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Exploring executive attention in emotion: ERP and fMRI evidence

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Contents

Preface

“Ist es Gefühl? oder ist’s Mutwill? Ihr ratet es nicht.“

Johann Wolfgang von Goethe

Evolution has given humans the ability to act in manifold ways. Not only can different stimuli be associated with different responses, each individual stimulus may also be reacted to in varying ways. This ability has remarkable evolutionary advantages and enabled humans to survive anywhere on this earth (and off it). However, it brings with it the problem of selection as not all possible reactions to one or several present stimuli can be performed at the same time. Even though living in an environment of various, at times conflicting, calls for action by stimuli, humans do show coherent, goal-directed behavior. As you are reading these words, there may be a cup of coffee standing by your side that you could drink, there may be somebody talking next door whose conversation you could join, or your back may hurt from an entire day at the desk suggesting a little walk. These stimuli and the associated action tendencies are more or less in conflict with reading this dissertation; nevertheless, you are able to do just that. Thus, there has to be a mechanism enabling detection of conflicting activations and resolution of this conflict by selection and commitment of resources according the the current goal. Cognitive neuroscience has ascribed these functions to what has been termed *executive control of attention* (Posner & DiGirolamo, 1998).

Several situations are supposed to trigger attentional control. Norman and Shallice (1986) list, among others, novelty and errors, but also dangerous situations. Danger, which is signaled by emotional stimuli, indicates specific relevance and importance of a situation for survival. Is it that these situations require efficient control of attention? It has been shown that emotional stimuli trigger alerting and orient spatial attention (Vuilleumier, 2005). However, little is known about an influence of *emotion* on executive control of attention.

From a slightly different perspective, emotion theorists argue in a similar direction. Scherer (1984, 1994) suggested that emotion plays a role in the decoupling of stimulus and response. How so? When moving beyond reflex-like stimulus-response mappings to an enlarged behavioral repertoire, the advantages of the fixed stimulus-response mappings, providing reliable, quick, and appropriate responses, should be retained. Emotions seem to fulfill these criteria as they rapidly evaluate stimuli regarding central needs and goals of the organism, prepare a response tendency, and provide the necessary motivational force to carry out an action. Thus, emotion may provide the means to rapidly exert attentional control in reaction to certain (namely emotional) stimuli.

The present dissertation aimed at this critical question, whether emotion may modulate the control of attention. A novel experimental design was applied that combined an emotional and an attentional perspective on behavior control. To gain insight into the time-course of integration, and the brain regions involved, data from electroencephalography and from functional magnetic resonance imaging were collected.

Previous research that motivated the experiments is discussed in Part I of the thesis. Part II describes the experiments conducted, followed by a discussion in Part III.

The contents of the individual chapters is briefly outlined. *Chapter 1* introduces the methods applied in the present thesis. The use of electroencephalographic measures was motivated by the high temporal resolution of this technique, whereas functional magnetic resonance imaging provides high spatial resolution. This enables inferences about temporal dynamics and involvement of brain areas in the interaction of emotion and executive attention. *Chapter 2* gives a definition of (executive) attention. It describes experimental tasks used to measure it and reviews previous research on executive control of attention. The chapter concludes with a life-span developmental and psychopathology view on executive attention, identifying associated changes in the neural underpinnings. The main goal of *Chapter 3* is to pursue the question of an emotion attention interaction. Therefore, information about emotion processing and its neural basis is given. As the effects of written and spoken emotional words were investigated in the present dissertation, a special section explores specifics of these verbal emotional stimuli. The core question of a modulatory influence of emotion on attention is addressed at the end of the chapter. The discussion then turns to interindividual differences in temperament and emotional state that are associated with attentional and emotional regulation in *Chapter 4*. The theoretical part concludes with *Chapter 5*, a summary of the main questions and hypotheses that motivated the experiments. To ease reception of technical details, *Chapter 6* describes those methodological parameters that were identical in all electrophysiological and functional magnetic resonance experiments. *Chapter 7* turns to a set of experiments with visually presented emotional words. The construction and rating of the words and the visual design used in the experiments is described. To further test the saliency of the chosen stimuli, a first behavioral study investigated the general attentional effects of the emotional words. The specific effects on executive control of attention were studied in two electrophysiological experiments with negative and positive emotional words. The former were also used in a functional magnetic resonance experiment. To test the validity and generalizability of the effects, a set of experiments studying the auditory modality with a different experimental paradigm are described in *Chapter 8*. In analogy to the previous chapter, stimulus construction and rating, as well as the experimental paradigm are delineated, followed by two electrophysiological experiments with positive and negative material. In the functional magnetic resonance experiment, the effects of emotionally negative words were studied. The last part of the dissertation discusses the main findings in *Chapter 9* and gives a perspective on possible future directions in *Chapter 10*.

Part I

Theoretical and empirical background

Chapter 1

Relevant cognitive neuroscience methods

The current chapter introduces the research methods relevant for the present thesis, with Section 1.1 focusing on the event-related potentials of the electroencephalogram, and Section 1.2 outlining the basics of functional magnetic resonance imaging.

The time that participants in a psychological experiment need to respond to a given task (reaction time, RT) can be highly informative about the underlying mental processes. When response times to different task conditions are compared, conclusions about similarities and differences between processing in these conditions, as well as the timing of these processes can be made (Donders, 1969; Posner, 1978). For example, participants are asked, to indicate the identity of a target letter (A, associated with a right hand response, or B, associated with a left hand response) that is surrounded by either identical, or different flanker letters (A or B). RTs may be longer when different letters are presented, suggesting that the flankers were perceived, processed, and elicited some form of conflict between a right and left hand response. The number of errors that participants make when performing a task is valuable as well, but often not as sensitive as RTs. Nevertheless, RTs and error rates are composite measures, comprising all processes from stimulus perception to response execution. Electrophysiological methods allow online measurement of these processes, e.g., identification of the exact point in time at which the conflict between opposing responses is detected. Also, neuroimaging yields data about the neural basis of the processes at hand. Therefore, the present thesis not only applied behavioral measures (RTs and error rates), but also electroencephalography and functional magnetic resonance imaging.

1.1 Event-related potentials of the EEG

This section only sketches the principles of event-related potentials of the electroencephalogram (EEG); for detailed information the reader is therefore referred to the pertinent literature (an excellent book was edited by Handy, 2004).

Electroencephalography. The EEG is an already “old” technique (Caton, 1875; Berger, 1929) that still offers advantages especially concerning temporal resolution. It is based on registering electrical fields from the scalp that are elicited by ionic currents in the brain (Gall, Kerschreiter, & Mojzisch, 2002). Pyramidal cells which represent 85% of neocortex neurons and are its major input and only output system (Nieuwenhuys, 1994) are arranged in a very regular manner with the cell body in deep layers III, IV and V of the cortex and the apical dendrites in more superficial layers I and II. Thus, their orientation is perpendicular to the neocortex surface. Postsynaptic potentials (PSPs) at apical or somatic sites lead to current flows and the neuron acting as a dipole. The EEG signal is based on temporal and spatial summation of PSPs of many neurons ($>10^3$). Excitatory PSPs (EPSPs) at apical and inhibitory PSPs (IPSPs) at somatic sites, and vice versa, cause the same polarity in the voltage changes of the EEG signal due to differential projection of the dipoles. Nevertheless, because of the asymmetry of the dipoles, the reflected signal changes form differently on the scalp surface. Thus, from the EEG signal alone a decision about the neural basis of a certain voltage fluctuation can not be made unambiguously (Kandel, Schwartz, & Jessel, 2000). The EEG signal is usually measured as the difference between the potentials of two different electrodes (Birbaumer & Schmidt, 2006). In most cases electrodes at positions that do not represent brain activity (such as nose, earlobes or mastoids) are used as references. The standard method of electrode placement on the scalp is the international 10-20 system (Jasper, 1958). Each electrode is positioned in relation to anatomical landmarks (nasion, inion, and the bilateral preauricular points). Brain activity registered with the EEG can be divided into spontaneous activity that is mainly caused by rhythmic thalamic afferences to cortical areas, and event-related activity; the latter being of interest in the next paragraph.

Event Related Potentials. ERPs are voltage fluctuations in the EEG that are directly related to sensory, motor, affective, or higher cognitive events or processes. In general, ERPs have much smaller amplitudes than spontaneously occurring voltage changes. Thus, to extract the event-related activity, the EEG of many recordings time-locked to a stimulus presentation is averaged (see Figure 1.1). The idea behind this technique is that the event-related activity in several time-locked recordings will have a characteristic identity whereas the spontaneous activity will randomly fluctuate. As a result, the averaging process should reveal the activity that is due to the event only (in the example above, the presentation of an A or a B). The resulting ERP consists of several wave forms (components) which are specific for a stimulus. Components occurring up to 100 ms after stimulus presentation are called *exogenous* (Schmidt & Schaible, 2001). Changes in the properties of these components are mainly due to the physical features of the stimulus.[1] The term exogenous is used as no higher order processes affect these early components. The very earliest wave forms up to 10 ms after stimulus presentation are also referred to as *brainstem potentials* (Birbaumer & Schmidt, 2006) as their components are generated by different relay nuclei in the brainstem. Components emerging between 10 and 100 ms are often differentiated into *primary evoked potentials* that are only found over the cortical projection area of the peripheral stimulus and *secondary evoked potentials* that are found over widespread cortical areas. The latter probably reflect comparative processes of stored information with the sensory input in associative cortices. Waveforms occurring later than 100 ms post stimulus are not dependent on the physical stimulus characteristics exclusively. They can also be modified by higher order psychological processes. So their primary source of variability lies within the organism and they are thus referred to as *endogenous*. (This applies for example to the detection and processing of a conflict between different response tendencies associated with simultaneously presented stimuli A and B.)

Analysis of ERP components is possible on several dimensions which are *topography*, *amplitude*, *polarity*, *latency* and *duration*. There are different types of inferences that can be made from these characteristics of the ERP components (Handy, 2004), all based on comparisons between different experimental conditions. ERPs of two conditions differing after 250 ms, for example, imply that the cognitive processes that differentiate the two conditions began to

[1]However, this definition may be too strict as, for example, some attentional processes seem to act already 50 ms poststimulus (e.g., Woldorff & Hillyard, 1991) and emotional stimuli also show some very early effects (see Chapter 3).

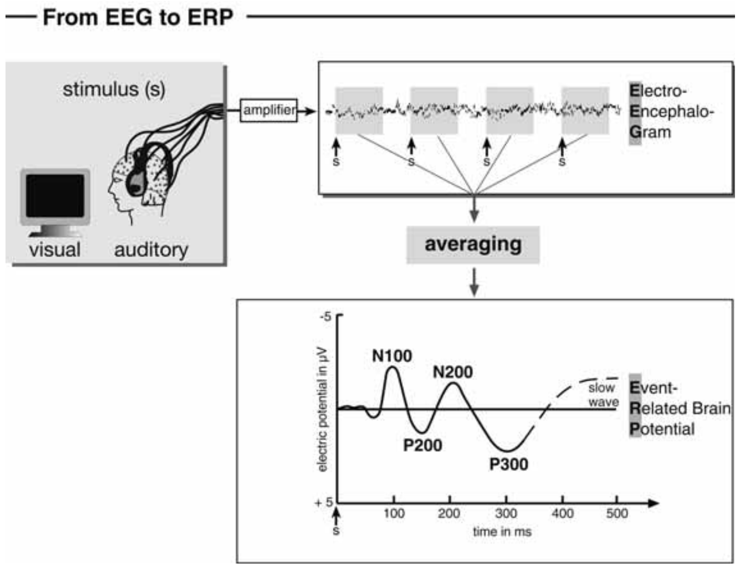

Figure 1.1: Simplified schema for the measurement of ERPs. Single EEG recordings are slightly modified by the presentation of a stimulus. After stimulus-locked averaging only the EEG modifications due to the stimulus are kept yielding characteristic potentials.

differ by 250 ms. This may seem to be unspectacular but there really is no other technique yielding this kind of result (especially with comparably high temporal resolution) in humans. Inferences can be even more significant when a specific deflection in the waveforms is a well-known component, i.e., it follows a circumscribed scalp distribution, some regularity concerning latency and polarity and a circumscribed relationship to experimental variables. (This is the case for the conflict-related N200, as will be explained in Section 2.3.1.) Variance in amplitude in such a component, e.g., that is related to two conditions can indicate different degrees of engagement of the associated cognitive process. As has been described, ERPs can yield valuable information; however, there are also several limitations. Inferences basing on the *lack of an effect* are problematic as ERPs sample only a subset of the total brain activity at a given point in time. The activity is only detectable at the scalp when the elements of a neuronal population activate (or deactivate) synchronously, and their geometric configuration is such that their activation summates. Another limitation concerns *scalp distribution differences* that must be caused by patterns of neural activity differing across conditions or time. However, from the ERP data alone it remains unclear what the exact nature of this difference is. The *polarity* of an ERP effect has to be interpreted with caution too. It does not only depend on neurophysiological factors, but also on the location of the reference electrode, the baseline against which the effect is compared, and the location and orientation of its intracerebral sources. Another point is that the averaging of EEG epochs relies on the assumption that the signal is invariant across the epochs. If there is variability, e.g., in the time of occurrence of the signal ("latency jitter") and the degree of variability varies between conditions, then *amplitude differences* may occur in the averaged ERP waveforms although the signal in the underlying epochs does not differ in amplitude. Another problem related to amplitude differences is that it is impossible to distinguish between (a) the degree of activity of the underlying structure causing the difference, or (b) the proportion of trials (in the averaged ERP) carrying the effect being responsible for the amplitude difference. The amplitude would then be informative about the probability of engagement of certain process. A last problem to be mentioned here is that all relations between neural activity and cognitive processes revealed by ERP data are *correlational*; causation can not be assumed. It is well possible that a component only reflects a cognitive process occurring downstream from the process of interest or that it is incidental to it. Especially this last point is similarly true for functional magnetic resonance imaging, as the next section will show.

1.2 functional Magnetic Resonance Imaging

Functional magnetic resonance imaging (fMRI) is relatively young, with the first blood oxygen level dependent (BOLD) fMRI reports in 1990 (Ogawa, Lee, Nayak, & Glynn, 1990; Turner, Kienlin, Moonen, & Zijl, 1990). A brief introduction is provided in the current paragraph, based on Brown and Semelka (2001).

Nuclear magnetic resonance. MRI utilizes an inherent property of all protons and neutrons; the particles constituting a nucleus possess a spin. The spin is associated with a magnetic dipole, with the properties of a small magnet. Only nuclei with an odd number of protons and neutrons possess a net spin and create a detectable nuclear magnetic resonance (NMR) signal. Hydrogen (H) is therefore mainly used by MRI as it consists of a single proton and has a net spin, and as it exists in large amounts in the human body. Outside of a magnetic field, the dipoles of the H protons are randomly aligned in different directions. When inside a static magnetic field, however, they align either parallel (low energy) or anti-parallel (high energy) to the magnetic field, with most spins aligned in parallel fashion. Aligning the nuclei causes them to precess around an axis along the direction of the field with a certain frequency (Larmor frequency v_0) which depends on the magnetic field strength B_0 and the gyromagnetic ratio γ which is a constant for each type of nucleus ($v_0=\gamma B_0$). The energy difference between dipoles aligned parallel or anti-parallel is the local equilibrium magnetization M_0. By placing the magnetic dipoles of H nuclei in the external magnetic field B_0, a macroscopic magnetization is created M_0, which is aligned with B_0. A radio-frequency pulse sent at the Larmor frequency v_0, creates an oscillating magnetic field B_1 that is orthogonal (xy plane) to B_0. The net field is then tipped slightly away, so that M_0 precesses around the new net magnetic field and creates a transverse magnetization M_{xy}. Turning the radio frequency pulse off causes M_0 to precess again around B_0, the longitudinal magnetization M_0 recovers and the transversal magnetization M_{xy} disintegrates. The time of recovery of longitudinal magnetization is called T1 relaxation. T1 varies between different substances, e.g., in water it is longer than in oils, but shorter than in solid-state bodies. Cerebro-spinal fluid in a 1.5 T field has a T1 of $\sim$4 s, gray matter of $\sim$1.2 s. Similar to the recovery of longitudinal magnetization, there is a loss of phase coherence in the transverse plane which is referred to as T2 relaxation. T2 is always less than or equal to T1. However, in practical MRI small differences in the static magnetic field at different spatial locations cause the Larmor frequency to vary across the body. The time constant for the observed decay is called the T2* relaxation time, and is always shorter than T2. The repetition time (TR) and the echo time (TE) are related to these relaxation parameters. The time period between two excitation (radio frequency) pulses is indicated by TR. The delay from an excitation pulse to the onset of data acquisition is referred to as TE. The sensitivity of a specific MRI measurement pulse sequence to different types of tissue partly depends on the combination of TR and TE values applied in that pulse sequence. This makes MRI highly versatile to measure different kinds of tissue, e.g., white or gray matter.

BOLD response. Ogawa et al. (1990) reported a study in which they found that T2* contrasts are sensitive to the degree of blood deoxygenation in the brain when rodents either breathed 100% pure oxygen or normal air. This describes the blood oxygen level dependent (BOLD) effect. It occurs because deoxygenated hemoglobin possesses magnetic momentum, whereas oxygenated hemoglobin does not. Therefore, deoxyhemoglobin creates local inhomogeneities in the magnetic field, causing brain regions with greater amounts of deoxyhemoglobin to show

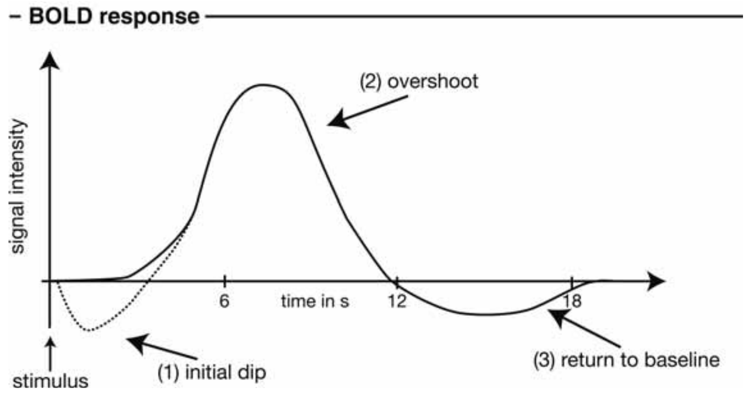

Figure 1.2: Signal intensity of a modulated BOLD response curve over time. There are three characteristic phases: (1) the initial dip, (2) overshoot of oxygenated blood, and (3) return to baseline state. The timing of these phases may vary, depending, e.g., on the brain region of interest.

greater signal loss in T2* weighted images. As the BOLD signal and neuronal activity are coupled, the BOLD effect can be used to detect brain activity non-invasively. In resting state, the brain accounts for ∼20% of the bodies oxygen consumption. The cortex has the highest need for oxygen with ∼8 ml per 100 g tissue per minute. White matter in contrast only consumes ∼1 ml per 100 g per minute. Neural activity leads to an enlarged demand for oxygen and consequently an enlarged amount of metabolites. These metabolites dilate local arterioles, thus increasing local blood circulation and the amount of oxygenated blood in that region. (In the example above, the presentation of a letter A or B will increase blood flow in areas involved in visual processing. Comparison of conflict eliciting stimuli with stimuli that are not associated with conflict will increase blood flow in areas involved in conflict processing.) The typical BOLD response displays three phases: (1) an *initial dip* which is thought to reflect an initial period of oxygen consumption, (2) a large *increase* above baseline, which reflects an oversupply of oxygenated blood to the area, and (3) the *return* to a state just slightly below baseline as the overshoot of oxygenated blood diminishes (see Figure 1.2). The BOLD response returns to baseline after a period of several seconds. Thus, the advantage in spatial acuity in the range of millimeters is accompanied by a decrement in temporal resolution from milliseconds in the EEG to several seconds in fMRI. Also, in contrast to the EEG, it is not the neural activity itself that is measured in fMRI, but a consequence of it; neural activity can only be inferred. Even though several studies showed that the BOLD signal is positively correlated with neural activity (for a review see Nair, 2005), conclusions about cognitive functions and related brain activity from fMRI should be made with care. Also, as described for ERPs, all relations between neural activity and cognitive processes revealed by fMRI data are correlational, not causal.

To make causal inferences, a combination with other measures like transcranial magnetic stimulation (TMS) or lesion studies is required. Another imaging technique is positron emission tomography (PET) which also yields images of functional brain activity, but is not applied in the present dissertation (see, e.g., Neil, 1993). Magnetoencephalography (MEG) is another interesting technique that is based on the registration of the magnetic fields generated when neurons are active. It is thus closer to the EEG that is based on the corresponding electric fields and has a similar temporal resolution. However, MEG has a slightly better spatial resolution.

To conclude, the application of EEG and fMRI in the current thesis enables some conclusions beyond what behavioral measures allow, specifically in regard to the time-course of cognitive processes as well as the brain regions involved in certain functions. The next chapters will therefore describe evidence that informed and motivated the present EEG and fMRI experiments.

Chapter 2

Executive control of attention

Attention has been viewed as a single unitary system, but also as separate systems underlying distinct functions related to "intensity" and "selectivity" (Kahneman, 1973). Intensity refers to different attentional states ranging from coma to the conscious awake state (Birbaumer & Schmidt, 2006) whereas selectivity refers to mechanisms that enable distribution of resources. Executive control of attention, which is investigated in the current thesis, does not describe attentional states, but relates to the detection of conflict between opposing activations, e.g., opposing response tendencies, and to the resolution of conflict by selection and commitment of resources (Posner & Petersen, 1990). The broadest conception of cognitive control includes functions such as shifting task sets, detection of errors and unfavorable outcomes, supervision of decision uncertainty and of response conflict. Discussing the convergence and divergence of these processes is beyond the scope of this chapter. The focus is, therefore, on response conflict, which ideally exemplifies the definition of executive attentional control as will be shown in this chapter.

First the function of attentional networks in general is outlined (Section 2.1), before concentrating on the executive control network of attention. Experimental paradigms to investigate executive attention are described in Section 2.2. Section 2.3 outlines the neural basis of executive attention, and Section 2.4 describes changes occuring in development, aging, and psychopathology.

2.1 Attention and its function

Attention can be described as "an organ system with networks of neural areas related to several major functions such as maintaining the alert state, orienting to sensory events and resolving conflict between responses" (p. 410, Posner, Rueda, & Kanske, 2007). The current thesis aims at investigating the influence of emotion on the latter function of attention, the resolution of conflict. Alerting and orienting of attention shall be briefly described in the next paragraph as understanding of these attentional functions also supports understanding of the distinct role of executive attention. Moreover, there is some evidence suggesting an influence of emotion on alerting and orienting (see, e.g., Vuilleumier, 2005). When examining emotion and executive attention it is therefore important to differentiate these modulatory effects from effects of emotion on other attentional functions.

Alerting describes the state of wakefulness and arousal of an organism. The general concept of alerting includes phasic (or exogenous) and tonic (or intrinsic) components (Hackley & Valle-Inclán, 1998; Sturm & Willmes, 2001). Tonic or intrinsic alertness, which is also referred to as vigilance (Gall et al., 2002), represents the cognitive control of wakefulness over extended periods of time. It is commonly measured with RT tasks in which no cue is presented. RT tasks in which a cue is presented prior to a target assess phasic or exogenous alertness, or the capacity of the organism to develop and maintain response readiness subsequent to external stimulation (Sturm et al., 2006). The consistent result, usually described as a warning effect, is a reduction of the RTs for targets that are preceded by cues. This effect is frequently accompanied by a reduction on the accuracy of the response (Posner, 1978). In the EEG a warning signal is followed by a negative shift, the contingent negative variation (Walter, Cooper, Aldridge, McCallum, & Winter, 1964), which has been interpreted as indexing expectancy. Lesion studies in stroke patients revealed an important role of the right hemisphere for tonic alertness (Howes & Boller, 1975; Ladavas, 1987). A PET study also identified an extensive right hemisphere network when participants waited for and rapidly responded to a centrally presented white dot (Sturm et al., 1999) or to a tone signal (Sturm et al., 2004). It has been proposed that the similarity of activation patterns under visual, auditory and somatosensory stimulation (Kinomura, Larsson, Gulyás, & Roland, 1996) supports the notion of a supramodal right-hemisphere network for the control of tonic alerting. Phasic alerting in contrast activated more left (Coull, Nobre, & Frith, 2001) or left lateralized fronto-parietal networks (Sturm & Willmes, 2001; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). Essential for alertness regulation are also several subcortical structures, in particular the locus coeruleus and the thalamus (for a review see Aston-Jones & Cohen, 2005).

Orienting of attention refers to the mechanisms that select information for further processing. It has primarily been investigated in vision, mainly for visual spatial processing. Classic experimental paradigms include visual search (e.g., Treisman & Gelade, 1980) and cueing tasks (Posner, 1980). In the latter, a cue that informs the participant about the spatial location of an upcoming target is presented prior to that target. In a valid condition the cue correctly predicts the target location, in an invalid condition the cue is misleading. Participants commonly respond faster to validly, as compared to invalidly cued targets. When the ERPs to the target stimuli are observed there is an amplification of early visual components P1, N1, and in some cases P2, over occipital electrodes for validly cued targets (for a review see Hillyard & Anllo-Vento, 1998). This amplification of scalp surface potentials represents attentional modulation of activity in the ventral-lateral extrastriate visual cortex (Gonzalez, Clark, Fan, Luck, & Hillyard, 1994). The sources of this attentional modulation have been identified by examining cue related activity. A large body of evidence supports a fronto-parietal network for orienting of attention including frontal eye fields, superior parietal lobe, and temporoparietal junction (Kastner, Pinsk, Weerd, Desimone, & Ungerleider, 1999; Corbetta, Kincade, Ollinger, McAvoy, & Shulman, 2000; Hopfinger, Buonocore, & Mangun, 2000, for a clear differentiation of top-down and bottom-up attentional processes see, e.g., Hahn, Ross, & Stein, 2006). Interestingly, this network seems to be also active when orienting attention to certain points in time (Coull, Frith, Büchel, & Nobre, 2000), or to semantic categories (Cristescu, Devlin, & Nobre, 2006).

The mechanisms and neural bases of *executive attention* are subject of the following sections.

2.2 Experimental tasks investigating executive attention

As explained above, the ability to show coherent goal-directed behavior even in the presence of distracting stimuli requires detection and resolution of conflict. How is it possible to experimentally investigate executive attention? Several tasks have been proposed that will be briefly outlined. The main principle always includes the presentation of stimuli with more than one dimension, one of which is task-relevant, the other(s) task-irrelevant. The critical comparison is between the following situations. The task-relevant and the task-irrelevant stimulus dimension can elicit the same action tendency yielding a congruent situation. This is compared with incongruent situations in which different actions are associated with the different stimulus dimensions. In the latter case the conflict between the different action tendencies has to be detected and solved, with reference to the current goal.

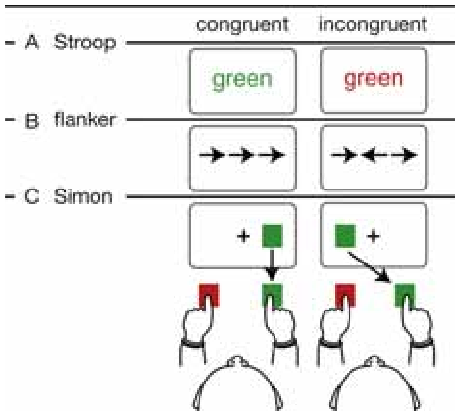

Figure 2.1: Conflict paradigms: The Stroop task (A) involves participants in naming the ink color of congruent and incongruent color words. In the flanker task (B) participants respond to a central stimulus surrounded by congruent and incongruent flanker stimuli. The Simon task (C) creates congruent and incongruent stimulus-response mappings.

The best-known paradigm is probably the so-called *Stroop* task developed by Stroop (1935). It's roots are nevertheless in Leipzig, as Cattell (1886) observed in his doctoral thesis supervised by Wilhelm Wundt that naming of colored patches aloud takes longer than reading a corresponding color word, e.g., "red" (MacLeod, 1991). Stroop combined ink color and word meaning to create incongruent stimuli (word meaning and ink color did not match) and control stimuli (colored squares). In the incongruent situation, two conflicting action tendencies are elicited and participants consequently needed longer to name the ink color of the incongruent compared to the control stimuli[1]. Subsequently, the task had been slightly modified substituting Stroop's control condition by congruent stimuli in which word meaning and ink color match (see Figure 2.1A, and, e.g., Dalrymple-Alford & Budayr, 1966). Some studies also included a different neutral condition in which non-color words or rows of XXX were presented in different ink colors to investigate possible facilitation effects in congruent stimuli (Sichel & Chandler, 1969;

[1]Stroop actually reported two more experiments in which he also investigated latencies in reading the word stimuli instead of color naming and the impact of practice on color naming.

Dalrymple-Alford, 1972). A large variety of other modifications including presentation modality is given by MacLeod (1991). For electrophysiological and neuroimaging studies a common modification concerns the response. Participants are not responding verbally but by button press which reduces movement artifacts (but also the conflict effect).

For the present thesis two other paradigms were adapted. The *flanker* task which was introduced by Eriksen and Eriksen (1974) and the Simon task developed by Simon and Small (1969). The original flanker task involved the participants in identification of a centrally presented target letter. Flanking letters requiring the same (congruent) or a different (incongruent) response were presented next to the target. As in the Stroop paradigm, participants needed longer to respond to incongruent as compared to congruent stimuli indexing the time necessary to process the conflict. Other authors used variants of this task with, e.g., arrows instead of letters, (see Figure 2.1B, and, e.g., Ridderinkhof & Molen, 1995).

In contrast in the *Simon* paradigm (Simon & Small, 1969)[2], conflict is introduced through incongruent stimulus-response mapping, making use of a tendency to respond with the body side on which a stimulus appeared. Simon and Small (1969) presented high- and low-pitched tones to either the right or left ear. Participants responded with either the right or left hand to one particular tone. Interestingly, participants response time was longer when stimulus presentation side and response hand side were different, even though the presentation side was task-irrelevant. The Simon task has also been adapted and modulated, e.g., to visual stimulation yielding comparable results (see Figure 2.1C, and, e.g., Craft & Simon, 1970).

2.3 Neural basis of executive attention

This section's title may be a bit overambitious as (1) the neural basis of executive attention is not fully understood yet. Also, (2) the section highlights the role of the N200 (Section 2.3.1) and of the anterior cingulate cortex (ACC, Section 2.3.2) in executive attentional control. This is not to imply that that these are the only relevant neural correlates of executive attention, however, they are of special interest in the present dissertation. The N200 is the first indicator of conflict processing in the ERP, and, as Chapter 3 will show, the ACC is not only relevant for executive attention, but also for emotion processing. Additionally, a P300 modulation in amplitude or latency has been observed in some conflict studies (Praamstra, Stegeman, Cools, & Horstink,

[2]See Simon and Rudell (1967) for an earlier publication that used a slightly different paradigm.

1998; Ent, 2002). Also, several prefrontal regions seem to be involved in executive control of attention. Section 2.3.3 provides a brief overview of the most relevant brain regions beyond the ACC.

2.3.1 The N200 of the event-related potential

The first reports of a fronto-central conflict N200 when directly contrasting response incongruent and congruent trials in an EEG experiment were based on a body of earlier electrophysiological evidence investigating response inhibition. In a flanker task, Gratton, Coles, Sirevaag, Eriksen, and Donchin (1988) reported data on the lateralized readiness potential (LRP), which had been found to be more negative over the contralateral compared to the ipsilateral motor cortex in choice RT tasks indicating the preparation of a response (Kornhuber & Deecke, 1965; Vaughan, Costa, & Ritter, 1968; Kutas & Donchin, 1980; Coles & Gratton, 1986; Smid, Mulder, & Mulder, 1987)[3]. Gratton et al. (1988) observed an enlarged early ipsilateral LRP in incongruent compared to congruent trials. This suggests that the flankers were processed and initially elicited a response tendency that conflicted with the current goal and was later inhibited. The LRP results imply the presence of a control mechanism that detects and solves conflict by inhibiting one of the opposing response tendencies.

An indication of such a control process had first been observed in a slightly different experimental paradigm, namely the go/no-go task. This design tests response inhibition such that participants respond in go trials, but withhold their response in no-go trials. No-go trials typically elicit a larger negativity, often around 200 ms, when compared to go trials, which has been referred to as ”no-go N200“ (Kok, 1986; Jodo & Kayama, 1992; Eimer, 1993; Schröger, 1993). It has mainly been interpreted as indexing action inhibition processes. As described above, incongruent flanker stimuli elicit a response tendency as measured in the LRP (Gratton et al., 1988). As this response tendency does not lead to an overt response; response inhibition can be assumed. It may be represented in an enlarged N200, similar to the no-go trials. Gehring, Gratton, Coles, and Donchin (1992) and others (Kopp, Rist, & Mattler, 1996) reported such an N200 in the flanker task which has henceforth been found by several other groups (Jonkman

[3]Kornhuber and Deecke (1965) referred to the potential as Bereitschaftspotential. Further investigation of the potential and computational formulae for deriving the LRP were developed by two groups in Groningen (e.g., Smid et al., 1987) and Illinois (e.g., Coles & Gratton, 1986). As Eimer and Coles (2003) noted, the term LRP originates from these investigations, even though the group in Groningen originally used the term “corrected motor asymmetry“.

et al., 1999; Ent, 2002; Bartholow et al., 2005; Riba, Rodríguez-Fornells, Münte, & Barbanoj, 2005; Riba, Rodríguez-Fornells, Morte, Münte, & Barbanoj, 2005; Zirnheld et al., 2004; Tsai, Young, Hsieh, & Lee, 2005; Peña, Lastra-Barreira, & Galdo-Alvarez, 2006; Krämer et al., 2007).

There are fewer studies on the Simon task in the ERP, and of those, only some directly contrasted responses to congruent with responses to incongruent stimuli. Carriero, Zalla, Budai, and Battaglini (2007) presented arrows pointing to the right or left and participants responded by releasing a right or left button correspondingly. The stimuli were either on the right or left side of fixation yielding congruent and incongruent situations. The authors found an N200 peaking between 200 and 250 ms that was enlarged for incongruent as compared to congruent trials, replicating the results from the flanker tasks.

In the Stroop task, incongruent as compared to congruent stimuli often elicit a negativity that peaks around 450 ms poststimulus and that has been termed N450 in the Stroop literature (West & Alain, 1999; Liotti, Woldorff, Perez, & Mayberg, 2000; West & Alain, 2000). Even though the N450 in the Stroop task peaks later than the N200 commonly observed in flanker tasks, in an extensive review, Folstein and Petten (2008) conclude that both potentials may represent similar mechanisms as they have a very similar scalp distribution and are both "similarly sensitive to manipulations of cognitive control" (p. 162).

Attempts to localize sources of the event-related potentials further support the claim that both, the N200 and the N450, index control processes. Liotti et al. (2000) presented Stroop stimuli to participants who either overtly or covertly named the ink color, or pressed a response button that was associated with the color. The authors found an N450 in all cases and also localized a dipole in the anterior cingulate cortex. Similarly, Carriero et al. (2007) report a dipole analysis that localized the N200 in a Simon task to the ACC. The conflict N200 effect in the flanker task has also been localized to the ACC in dipole analysis (Veen & Carter, 2002b). As reported above, an N200 is also observed in go/no-go tasks. Mathalon, Whitfield, and Ford (2003) found a no-go N200 that was correlated to activity in the ACC when the same participants performed the task twice, in EEG and in fMRI.

In conclusion, there is converging evidence from different conflict tasks that connects conflict resolution to a fronto-central negativity. The exact timing of this deflection varies across tasks, but localization of the negativity consistently found sources in the anterior cingulate cortex. The next section reviews imaging studies of conflict tasks that may help to be more specific in regard to the neuroanatomical basis of conflict processing.

2.3.2 The anterior cingulate cortex

Source localization of the conflict related ERP negativity already alluded to the possibility that the anterior cingulate cortex is involved in conflict processing. However, as described in Section 1.1, these claims about the involvement of certain regions of the brain in mental functions must be made with caution when solely based on EEG data. Functional imaging with fMRI or PET can test localization hypotheses more directly (see Section 1.2). The current section will therefore review and summarize neuroimaging studies on conflict tasks.

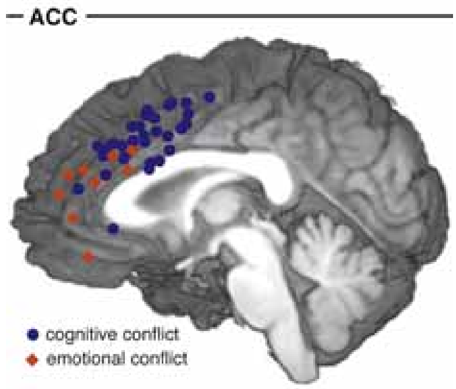

Figure 2.2: Peak activations from the conflict studies listed in Table 2.1 are displayed for cognitive conflict (Stroop, flanker, Simon in blue) and emotional conflict and distractors (in red, see Section 3.4.3 for a detailed description of the tasks included).

The probably first study to examine *flanker* effects in the fMRI was conducted by Botvinick, Nystrom, Fissell, Carter, and Cohen (1999). They presented an arrow flanker task, similar to the one depicted in Figure 2.1B and found activation for incongruent over congruent trials in anterior cingulate cortex. The activation peak was in the dorsal portion of the anterior cingulate, posterior to the genu of the corpus callosum. Even though there are a few null-results regarding flanker conflict activation in the ACC (e.g., Hazeltine, Poldrack, & Gabrieli, 2000), most of the studies to date did find ACC involvement. Table 2.1 gives an overview of imaging studies that reported ACC activation in the flanker task. It also includes ACC activations from Stroop and

Simon studies, and a few experiments looking at emotional conflict and the effects of emotional distractors. Figure 2.2 displays the reported peak activations from the studies listed in Table 2.1 on a standard brain (Talairach & Tournoux, 1988, MNI coordinates were transformed to Talairach space before inclusion). It is apparent that the activation peaks for the conflict studies (displayed in blue) mainly fall into the dorsal portion of the ACC, but vary in regard to the exact location in the dorsal ACC. Also, activations have been reported in the right as well as in the left ACC leaving it open as to whether there are hemispheric differences.

Study	Method	Task	Contrast	x	y	z	H
Stroop							
Pardo et al. (1990)	PET	Stroop	inc - con	-10	29	30	L
				-7	27	30	L
				-17	35	28	L
George et al. (1994)	PET	Stroop	inc - con	-22	24	32	L
Carter et al. (1995)	PET	Stroop	inc - con	10	8	48	R
George et al. (1997)	fMRI	Stroop	inc - neu	-22	8	28	L
Taylor et al. (1997)	PET	Stroop	inc - neu	-3	35	18	L
Bush et al. (1998)	fMRI	counting Stroop	inc - con	12	9	34	R
Derbyshire et al. (1998)	PET	Stroop	inc - con	-2	14	40	L
				0	2	48	-
Carter et al. (2000)	fMRI	Stroop	inc - con	0	15	41	-
MacDonald et al. (2000)	fMRI	Stroop	inc - con	4	1	43	R
Banich et al. (2001)	fMRI	Stroop	inc - neu	2	16	42	R
Peterson et al. (2002)	fMRI	Stroop	inc - con	11	17	22	R
				-10	15	24	L
Fan, Flombaum, et al. (2003)	fMRI/EEG	Stroop	inc - con	-4	38	30	L
Egner and Hirsch (2005)	fMRI	Stroop	inc - con	18	8	46	R
Veen and Carter (2005)	fMRI/EEG	Stroop	rinc - sinc	1	26	28	R
			sinc - scon	7	18	42	R
Wagner et al. (2006)	fMRI	Stroop	inc - con	4	15	40	R
				-8	21	38	L
Mohanty et al. (2007)	fMRI	Stroop	inc - con	4	14	36	R
Simon							
Peterson et al. (2002)	fMRI	Simon	inc - con	11	17	20	R
				-10	13	24	L
Fan, Flombaum, et al. (2003)	fMRI/EEG	Simon	inc - con	-16	32	-4	L
				-6	46	12	L
flanker							
Veen et al. (2001)	fMRI	flanker	rinc - (sinc = con)	-3	32	31	L
Fan, Flombaum, et al. (2003)	fMRI/EEG	flanker	inc - con	-8	28	24	L
Fan et al. (2005)	fMRI	flanker	inc - con	6	36	26	R
Fan et al. (2007)	fMRI	flanker	inc - con	-8	24	38	L

continues on next page...

Study	Method	Task	Contrast	x	y	z	H
Luks et al. (2007)	fMRI	flanker	icinc - iccon	2	19	32	R
				1	18	45	R
			ncinc - nccon	2	2	39	R
				10	19	34	R
				-4	4	37	L
Fan et al. (2008)	fMRI	flanker	inc - con	-6	-8	50	L
Emotional conflict							
Etkin et al. (2006)	fMRI	word-face	inc - con	-10	48	0	L
Haas et al. (2006)	fMRI	word-face	inc - con	4	32	26	R
Haas et al. (2007)	fMRI	word-face	inc - con	6	42	-16	R
Egner et al. (2008)	fMRI	word-face	inc - con	-12	44	-2	L
Emotional distractors							
George et al. (1994)	PET	emotional Stroop	inc - con	-22	24	28	L
				-4	26	20	L
Whalen, Bush, et al. (1998)	fMRI	emotional counting Stroop	inc - con	-3	39	15	L
Bishop et al. (2004)	fMRI	matching task	threat - neu	-2	50	18	L
Engels et al. (2007)	fMRI	emotional Stroop	inc - con	-2	54	10	L
Mohanty et al. (2007)	fMRI	emotional Stroop	inc - con	-2	44	20	L

Table 2.1: Overview of imaging studies assessing the cognitive (Stroop, Simon, flanker; for a description of the counting Stroop see Chapter 2.4) and emotional conflict (see Section 3.4) effects. X, y and z coordinates are the stereotactic coordinates as reported by the authors. (r/s/ic/nc/)inc = (response/stimulus/informatively cued/neutrally cued) incongruent; con = congruent

A larger number of investigations examined the role of the ACC in *Stroop* incongruency (see Table 2.1). Pardo et al. conducted a PET study already in 1990, in which they presented blocks of incongruent and congruent stimuli to participants. Activations were found in several areas in the dorsal ACC. Similarly, Peterson et al. (2002) found dorsal ACC activation bilaterally for incongruent trials in the *Simon* task (see also Table 2.1 for other studies on the Stroop and Simon task).

There are a few studies including more than one conflict task, which enables direct comparison of activations elicited by the different forms of conflict. Peterson et al. (2002) had participants not only perform the Simon task, but also applied a Stroop task. Regions activated in both tasks included the anterior cingulate cortex which also showed a very similar time course of the BOLD response. The authors concluded that ”the resolution of cognitive interference that is generated by competing task demands is accomplished by similar [...] functional networks in the brain” (p. 439). A comparison of Stroop, Simon, and flanker tasks was done by Fan, Fossella, Sommer, Wu, and Posner (2003). Even though they found anterior cingulate activity in each of the tasks, they also report activations in several other areas that were task specific.

The anterior cingulate was also sensitive to different forms of conflict in a study by Wager et al. (2005) who included a flanker task, a go/no-task, and a stimulus-response incompatibility task. In this task arrows pointing to the right or left were presented at the center of the screen. Participants were either pressing a button with the hand that the arrow pointed to (congruent), or with the other hand (incongruent). Several regions, including the anterior cingulate cortex, were commonly activated. Again, there were also other areas with less conclusive activation patterns. The authors' interpretation, based on extensive correlational analyses, was that the "brain mechanisms for interference resolution may be common, but a participant may recruit them to different degrees in different tasks" (p. 338). Whatever may cause the specific activations in different conflict tasks, the common ACC activation suggests that this region is vital for conflict processing.

A recent meta-analysis corroborates this view. Nee, Wager, and Jonides (2007) collected peak activations from 47 neuroimaging studies on different conflict tasks, including Stroop, Simon, and flanker tasks, but also the go/no-go paradigm and the stop signal task[4]. Also, Nee et al. (2007) differentiated between Simon and stimulus-response compatibility tasks as described in the previous paragraph. The authors then conducted a density analysis examining the spatial consistency among reported peaks and located brain voxels in which the density of reported peak activations exceeds what would be expected by chance (for a detailed description of the technique and previous applications see Wager, Phan, Liberzon, & Taylor, 2003; Wager, Jonides, & Reading, 2004). When all 47 studies were included in the analysis, significant clusters were found in the anterior cingulate cortex, the dorsolateral prefrontal cortex, the inferior frontal gyrus, and the posterior parietal cortex. Density analyses of the tasks individually revealed similar but not identical networks for the conflict tasks.

The very consistent finding of ACC activation for incongruent compared to congruent conditions in different tasks suggests that it plays a key role in the processing of conflict. As mentioned above it is often found as part of a network of areas. The following section will

[4]In the stop signal task participants are required to respond to a stimulus, but are told to withhold their response in some trials in which another stimulus (the stop signal) is presented. Varying the onset of the stop signal modulates the difficulty of the task. Conflict is supposed to be elicited by the readied response and the competing inhibition of this response through the stop signal.

therefore briefly review other areas involved in conflict processing, discussing the potential functional relations.

2.3.3 Other regions involved

The extensive meta-analysis by Nee et al. (2007) suggested a network of areas involved in conflict processing including the anterior cingulate cortex, but also dorsolateral prefrontal cortex, inferior frontal gyrus, and posterior parietal cortex.

Especially the dorsolateral prefrontal cortex (DLPFC) has received a lot of interest and has become part of network models for executive attentional control (Carter et al., 1998; Botvinick et al., 1999; Veen et al., 2001; Veen & Carter, 2002a; Botvinick, Cohen, & Carter, 2004). These accounts ascribe conflict monitoring functions to the ACC, i.e., it detects the occurrence of conflict between responses, stimuli, and task representations (Veen & Carter, 2002a; Weissman, Giesbrecht, Song, Mangun, & Woldorff, 2003; Milham, Banich, & Barad, 2003). The regulatory top-down component of executive control is attributed to the DLPFC that acts upon conflict signals from the ACC. The alternative account is that activation of the ACC reflects not (only) conflict detection, but the application of top-down executive attentional control (Posner & DiGirolamo, 1998). Support for the latter view comes from a study applying a cued global/local conflict task (Weissman, Gopalakrishnan, Hazlett, & Woldorff, 2005). Stimuli were global letters composed of smaller local letters. The cue told participants whether to react to the global or local letters which either mapped to the same response (congruent) or to a different response (incongruent). A region involved in executive attentional control (1) should show cue related activity that is increased by local compared to global cues as demands on these processes increasing attention to task-relevant stimuli are greater for local features (Navon, 1977; Stoffer, 1993, 1994). (2) This activation should decrease with practice (Norman & Shallice, 1986; Weissman, Woldorff, Hazlett, & Mangun, 2002). (3) Activation should be stronger for incongruent compared to congruent trials. (4) Participants showing strong conflict activation should exhibit reduced behavioral interference effects. Interestingly it was the ACC that showed exactly this response pattern suggesting that it is involved in top-down executive attentional control. The DLPFC showed similar activation to the cue, but in contrast to the ACC it was not activated by incongruent compared to congruent stimuli. Others also argued for an extended role of the ACC in executive attention beyond conflict monitoring (Hopfinger et al., 2000; Weissman, Mangun, & Woldorff, 2002; Woldorff et al., 2004; Aarts, Roelofs, & Turennout, 2008; Gajewski, Stoerig, & Falkenstein, 2008). The exact function of the DLPFC is therefore still debated.

The role of the inferior frontal gyrus (IFG) in executive control is also not fully understood yet. It is often associated with inhibitory processes, particularly the right IFG, e.g., in control of task sets (Brass & Cramon, 2004; Aron, Monsell, Sahakian, & Robbins, 2004) and interference resolution (Herrmann et al., 2001). Also, patients with damage in this region show deteriorated inhibition (Clark et al., 2007). However, as the IFG is also often activated in tasks not requiring inhibition (Duncan & Owen, 2000), clearly more work is necessary.

In conclusion, a neural network of areas is involved in executive control of attention. The role of each component in the network is not entirely clear; however, there is evidence relating the ACC to conflict detection and resolution.

2.4 Executive attention in development, aging, and psychopathology

The present thesis aimed at investigating influences of emotion on executive attention. It is therefore informative to review research on other factors that influence executive attention in order to see how these modulations are reflected in electrophysiology and imaging. This possibly helps to formulate concrete and directional hypotheses about what an influence of emotion on conflict processing might look like.

Development. Rueda, Rothbart, McCandliss, Saccomanno, and Posner (2005) presented a version of the arrow flanker task to 4 and 6 year old children. These age groups were selected because executive attention as measured by conflict tasks strongly develops during this period (Rueda, Posner, & Rothbart, 2005). In comparison to younger children, older children showed a reduced flanker interference that was accompanied by the presence of a frontal negativity in the ERP for incongruent compared to congruent trials. However, after a training period of 5 days, the 4 year olds also showed this frontal conflict negativity. This study provides strong evidence that a conflict negativity in the ERP emerges as executive attention (i.e., the ability to efficiently process conflict) emerges in childhood development. Two studies in adolescence show that the conflict N200 is still subject to change later in development. Ladouceur, Dahl, and Carter (2004) also used an arrow flanker task in 9 to 17 year olds who they split into a younger (mean age =

12.2) and an older group (mean age = 15.8). They only observed a conflict N200 in the older group. The lack of an N200 conflict effect in the younger group contrasts the findings of Rueda, Rothbart, et al. (2005); they may however be due to the small sample size (n = 5 in the younger and n = 6 in the older group) and consequently reduced power. Nevertheless, in a more recent study (Ladouceur, Dahl, & Carter, 2007) the authors examined a larger population including also adults (young adolescents: n = 15, mean age = 12.4; older adolescents: n = 15, mean age = 16.5; adults: n = 16, mean age = 28.7). Even though there was a small negativity for incongruent trials at frontal electrode sites in the young adolescents, it did not reach significance. The two older groups did show reliable N200 conflict effects. If statistical power is not the problem, the lack of an effect in the younger adolescence may be due to differences in the experimental procedures. Rueda, Rothbart, et al. (2005) used a version of the flanker task that was especially designed for children using animals instead of simple arrows (Rueda, Posner, & Rothbart, 2004) whereas Ladouceur et al. applied the standard version of the arrow flanker task which may be more difficult for the younger adolescents. In conclusion, the conflict N200 seems to emerge as executive attention develops. The studies in adolescence hint at the possibility that the amplitude of the conflict N200 still increases when conflict processing becomes more efficient in later development.

Aging. Evidence for altered conflict processing in older adults comes from a study on a version of the Stroop task in which participants were in some blocks told to name the ink color, in others to read the word (West, 2004). Critically, there were also mixed blocks in which a cue told the participant before each trial what the task for the present trial was (color/word). In the standard Stroop task (naming the ink color) the older group (mean age = 72.2) showed a larger conflict effect than the younger adults (mean age = 21.4). When reading the word, Stroop interference of the same magnitude was observed in both age groups. The authors also observed a conflict negativity (N450) that was reliably present in the younger group. In the older adults the conflict negativity was only present in the mixed blocks and ceased to be significant when the task was constant throughout a block. The results are less clear than those for the development of executive attention, but point in a similar direction. Efficient conflict processing seems to be related to the presence of a conflict negativity and to its amplitude.

Psychopathology. The current paragraph reviews studies of executive attention in patients with a focus on attention deficit hyperactivity disorder (ADHD), and side notes on Schizophrenia, and Huntington's disease. ADHD is the classical case of lack of self control, characterized by pervasive behavioral symptoms of hyperactivity, impulsivity and inattention, mainly beginning in childhood (for a review see Castellanos, Sonuga-Barke, Milham, & Tannock, 2006).

Pliszka, Liotti, and Woldorff (2000) had 11 year old boys with and without ADHD perform a stop signal task in which a stop signal followed with variable onset on a go signal eliciting conflict between the already activated response and its inhibition (see Section 2.3.2). Healthy boys succeeded more often in inhibiting a response to the stop signal than ADHD boys. Interestingly, healthy boys also showed a much larger N200 response in stop trials compared to the ADHD children. A very recent study provided similar results in a flanker task (Albrecht et al., 2008). They investigated three groups of 8 to 15 year old children (1) with ADHD, (2) their unaffected siblings, and (3) unrelated unaffected controls. There was a linear trend between RTs and "genetic concordance with ADHD", i.e., RTs were longest in ADHD children, intermediate in their siblings, and shortest in controls. The ERP results parallel the behavioral results with a reduced conflict N200 in ADHD children, an intermediate N200 in the sibling group, and largest N200 amplitudes in the control children. These data from children with ADHD corroborate the conclusion drawn from the developmental and aging studies that more efficient conflict processing is reflected in an enlarged conflict N200 amplitude.

For ADHD there are also two fMRI studies investigating ACC activation to conflict. Bush et al. (1999) applied a counting Stroop task (Bush et al., 1998) in which varying numbers of number words were presented on the screen. The participants' task was to indicate how many number words were presented, i.e., "three three" yielded an incongruent trial. Neutral trials consisted of none-number words, e.g., "cat cat". The authors only reported statistical tests for the two experimental groups separately, but described increased RTs and a larger conflict interference in adults with ADHD (age range 22 - 47) compared to healthy controls. In addition, only the healthy controls showed activation in the ACC to incongruent compared to neutral trials. The ADHD group did not activate the ACC. Results from an intervention study also point in the direction that recruitment of the ACC is necessary for efficient conflict processing. Lévesque, Beauregard, and Mensour (2006) had 10 year old ADHD children randomly assigned to a control and an experimental group that received neurofeedback training (for details see

Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003). The children in the experimental group showed improvement in accuracy in the counting Stroop task from a pre- to a post-test, whereas the control group did not change. In the pre-test neither group showed ACC activation, in the post-test however, the training group, not so the control group, showed ACC activation for incongruent over neutral trials. As for the N200, ACC activation for conflict seems to be stronger in participants capable of efficient conflict processing.

In line with the results is also a study in schizophrenics revealing larger Stroop interference for the patient group, but an attenuated conflict N450 amplitude (McNeely, West, Christensen, & Alain, 2003). One study observed prolonged RTs in patients with Huntington's disease (Beste, Saft, Andrich, Gold, & Falkenstein, 2008) who are known for ACC dysfunction (Reading et al., 2004; Beste et al., 2007). In a flanker task these patients exhibited an attenuated conflict N200 as well.

2.5 Summary

There are a few main points which were the aim of the current chapter. Executive control of attention strategically selects information to solve conflict among competing responses, also inhibiting stimuli and associated action tendencies that are not in line with current goals. Experimentally this can be tested with Simon, flanker, or Stroop tasks that yield prolonged reaction times to incongruent stimuli. Conflict is detected rather early as indexed in the N200 response to incongruent stimuli that seems to be generated in the anterior cingulate cortex. Neuroimaging studies confirm the involvement of the ACC as part of a neural network for executive attentional functions. Stronger activity in this network, i.e., larger N200 amplitudes, or a stronger BOLD response, seems to be associated with enhanced efficiency of executive control of attention, as data from development, aging, and psychopathology suggest. The next chapter first turns to a general description of emotion, however, only to come back to executive control and its potential modulation by emotion.

Chapter 3

Emotion and its influence on attention

The current Chapter informs about emotion (Section 3.1) and its neural basis (Section 3.2). The main goal is to elucidate the rapid nature of emotion detection and the pivotal role emotion plays for behavior regulation. The next Section 3.3 turns to specifics of emotional verbal stimuli as these were used in the present thesis. The last Section 3.4 constitutes the heart of the chapter, describing previous research on effects of emotion on attention.

3.1 Definition and approaches to emotion

Emotions are episodic, relatively short-lived psychophysiological reaction patterns that result from evaluation of a stimulus concerning its relevance for the organism (Keltner & Gross, 1999; Clore & Ortony, 2000). A stimulus that has the ability to elicit these reaction patterns is henceforth referred to as an emotional stimulus. Emotions incorporate action tendencies, bodily changes and subjective feeling of the emotion, whereby the latter is not without dispute as being an essential part of emotion (LeDoux, 1996). Important for the current discussion is the differentiation between emotions and moods, as emotions are shorter in duration (Ekman, 1994) and have an intentional character, i.e., they relate to a stimulus (Frijda, 1994). Even though most researchers would probably agree to this definition of emotion, there is large variation in the perspectives on (1) how cognitive and physiological emotional processes relate, (2) which different emotional patterns exist and how they can be classified, and (3) what constitutes the neural basis of emotion.[1]

Discussion of the first point had been initiated by the proposal of James (1884) and Lange (1885) stating that emotions are nothing but patterns of bodily changes that occur in the presence

[1]These questions are of course interrelated, as e.g., insight in the neural basis of emotion may support understanding of emotion classifications, etc.

of emotional stimuli. This account was challenged by Cannon (1927, 1931) on the basis of data including the finding that surgical separation of the viscera from the brain in animals did not impair emotional behavior and that autonomic activity cannot differentiate separate emotional states. However, more recent studies provided evidence against Cannon's claims showing, e.g., that different emotions are accompanied by distinct activity in the autonomic nervous system (Ekman, Levenson, & Friesen, 1983). The current consensus seems to be a somewhat modified James-Lange account of emotion in which bodily feedback at least modifies the experience of emotion (Dalgleish, 2004). Cognitive emotion theories also support such an interaction of bodily information and cognition in emotion generation, claiming that interpretation of the ambiguous autonomic state, depending on the social and cognitive context, is determining which emotion is felt (Lazarus, 1982; Schachter & Singer, 1962).

Along with different perspectives on how emotion arises come different classifications of emotions. Originating from Darwin's work there is the idea of a limited set of fundamental innate *"basic" emotions* (Darwin, 1872). Supporting evidence shows, e.g., that some emotional facial expressions are recognized in different cultures (Ekman & Friesen, 1971). The particular set of emotions varies but most often included are: anger, fear, sadness, disgust, happiness, and surprise (see, e.g., Cornelius, 1996). A lot of variability in emotional responses to stimuli can also be explained with the *dimensional factors* valence, ranging from negative/unpleasant to positive/pleasant, and arousal, ranging from low arousing to high arousing (see, e.g., Bradley & Lang, 1994). The cognitive approach, in contrast, claims that emotions are the products of *appraisal processes* that may yield as complex social emotions as shame, schadenfreude, or pride (see, e.g., Scherer, 2003a). Of course these classification approaches are not necessarily exclusive in their description of emotion, e.g., basic emotions such as anger or fear can be located in the dimensional space of valence and arousal (for an example using emotional affective pictures see Libkuman, Otani, Kern, Viger, & Novak, 2007).

The question of the neural basis of emotion will be discussed in the following section.

3.2 Neural basis of emotion

Explaining the neural basis of emotion in its entirety as it is known to date is beyond the scope of this section. The focus is on ERP evidence that demonstrates early detection of emotional stimuli (Section 3.2.1). Later components of the ERP are also sensitive to emotion in different types of stimuli but are not discussed here (for examples of late effects in faces and words see Batty & Taylor, 2003; Kanske & Kotz, 2007). The most relevant brain structures for the present dissertation are the amygdala (Section 3.2.2) and the ACC (Section 3.2.3), the latter also plays a role in executive control of attention. Section 3.2.4 briefly reviews the role of some other brain areas involved in emotion processing.

3.2.1 Early effects in event-related potentials

A lot of the ERP evidence on emotional stimuli comes from face processing (for a recent review see Vuilleumier & Pourtois, 2007). Faces seem to be recognized by a specialized neural system in the inferior temporal cortex very rapidly (less than 200 ms) as indexed by an early negativity over posterior electrodes, the N170 (Bentin, Allison, Puce, Perez, & McCarthy, 1996; George, Evans, Fiori, Davidoff, & Renault, 1996; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002; Carmel & Bentin, 2002). Effects of the emotional expression of faces have been described in different components following the N170, i.e., after the face has been recognized and processed (e.g., the early posterior negativity, EPN, Sato, Kochiyama, Yoshikawa, & Matsumura, 2001; Schupp et al., 2004). Interestingly however, the N170 itself can also be modulated by the emotional expression of the face, apparently independently of the specific emotional valence as has been shown for fear, disgust and happy faces (Pizzagalli et al., 2002; Campanella et al., 2002; Batty & Taylor, 2003; Eger, Jedynak, Iwaki, & Skrandies, 2003; Miyoshi, Katayama, & Morotomi, 2004; Ashley, Vuilleumier, & Swick, 2004). This suggests that emotion must be detected even before the face is processed. Indeed, emotion effects have also been found in much earlier time-windows, e.g., on the P1 over posterior electrodes (Pizzagalli, Regard, & Lehmann, 1999; Streit et al., 2003; Eger et al., 2003; Batty & Taylor, 2003; Pourtois, Dan, Grandjean, Sander, & Vuilleumier, 2005) and on several fronto-central components elicited around 120 ms poststimulus (Eimer & Holmes, 2002, 2007). The question arises how emotion can be detected before a stimulus is processed. As will be shown in the next section, the amygdala plays a central role in this phenomenon [2]. Early ERP effects of verbal stimuli have also been observed and will be discussed in Chapter 3.3.

[2]It is not implied, however, that the early ERP effects are direct correlates of amygdala activity, which lies too deep in the medial temporal cortex to generate electric fields that could be detected at scalp surface

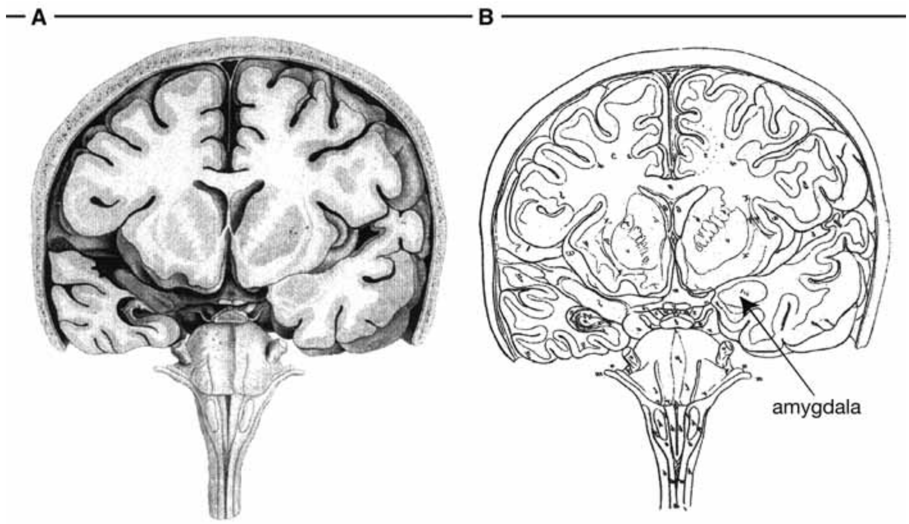

Figure 3.1: The amygdala (A) as originally described by Burdach (1819-1820) and (B) in his outline drawing. Current literature added several other nuclei to the amygdala, for a detailed discussion see Swanson and Petrovich (1998) from where a reproduction of the Figure was adapted.

3.2.2 The amygdala

The amygdala is a group of nuclei in the medial temporal lobes. It had been first described by Burdach (1819-1820) as "Mandelkern" ("almond-shaped nucleus"; see Figure 3.1). Its first involvement in emotion was indicated by a study in which the temporal lobes had been removed in rhesus monkeys yielding a characteristic set of behaviors including a loss of emotional reactivity and exploratory behavior (Kluver & Bucy, 1937). Later it was shown that lesions of the amygdala are sufficient to elicit most symptoms of the "Kluver-Bucy syndrome" (Weiskrantz, 1956) and also lead to disrupted social behavior accompanied by a fall in social standing (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). More recent studies replicated these results with better localized lesions (Murray, Gaffan, & Flint, 1996; Meunier, Bachevalier, Murray, Málková, & Mishkin, 1999) and in humans (Terzian & Ore, 1955; Aggleton, 1992).

Single cell recordings from the amygdala in animals showed its sensitivity to faces (Leonard, Rolls, Wilson, & Baylis, 1985), dynamic social stimuli like approach behavior (Brothers, Ring, & Kling, 1990), and fear conditioned stimuli (Blanchard & Blanchard, 1972; LeDoux, 1995, 2007). Also, lesion studies in humans showed that the amygdala is involved in processing of emotional facial stimuli, especially fearful faces (Adolphs, Tranel, Damásio, & Damásio, 1994;

Young et al., 1995; Calder et al., 1996), but also auditory fear signals (Scott et al., 1997). Early neuroimaging studies corroborated these results, finding amygdala activation for fearful faces with PET and fMRI (Morris et al., 1996; Breiter et al., 1996). This activation is even found when the faces are presented subliminally (Whalen, Rauch, et al., 1998; Morris, Ohman, & Dolan, 1998) and when fearful faces are presented to blindsight patients (Morris, DeGelder, Weiskrantz, & Dolan, 2001). The amount of imaging studies finding amygdala activation for emotional stimuli has increased largely in the last years. In a recent meta-analysis on just visual experiments, Sergerie, Chochol, and Armony (2008) were able to include 148 studies, even though they applied very strict inclusion criteria, such as report of information for effect size computation. Interestingly, these authors reported a significantly larger effect size for positive compared to negative emotional stimuli, which also held when only those studies were included that investigated both types of stimuli (N = 13). When activations were grouped into basic emotional categories, happy stimuli elicited stronger effect sizes than either fear or disgust. The authors concluded that the amygdala is sensitive to all visual emotional stimuli, regardless of valence. Strong evidence for this claim comes from a recent study. Lanteaume et al. (2007) were able to directly stimulate the amygdala in epileptic patients and also found increased positive and negative affective states after stimulation.

Two afferent routes to the amygdala have been described (Blanchard & Blanchard, 1972; LeDoux, 1995). Via a *slow cortical pathway* the amygdala receives complex information that has been processed through the visual cortex. The pathway includes: retina - lateral geniculate nucleus of the thalamus - V1 - V2,V4, inferotemporal areas - amygdala. A *fast subcortical pathway* directly projects from the thalamus to the amygdala, circumventing the visual cortex and providing crude sensory information. It includes: retina - superior colliculus - pulvinar - amygdala. Pessoa (2005) pointed out that this subcortical pathway has been documented in rats (Doron & Ledoux, 1999; Shi & Davis, 2001; Linke, Lima, Schwegler, & Pape, 1999), but not yet fully in primates for the visual domain. In contrast, in audition a subcortical pathway has already been shown to exist in primates (Campeau & Davis, 1995; Armony, Servan-Schreiber, Romanski, Cohen, & LeDoux, 1997; Doron & Ledoux, 1999). It includes cochlea - brainstem nuclei - medial geniculate nucleus of the thalamus - amygdala. However, there is also some evidence for a thalamo-amygdala pathway in vision in humans. Hamm et al. (2003) for example investigated fear conditioning of visual stimuli in a cortically blind patient who had suffered strokes destroying the visual cortex bilaterally. No visual evoked potentials of the ERP could be elicited. Nevertheless, a visual stimulus (a line drawing of an airplane), after having been paired with an aversive electric shock, potentiated the startle response just as in healthy controls with an intact visual cortex. In consequence, the amygdala, which is essential for fear conditioning (Bechara et al., 1995) must have received input via a subcortical route (for other evidence see also Morris et al., 1998; Morris, Ohman, & Dolan, 1999; Morris et al., 2001). This suggests that the amygdala is activated automatically by emotional stimuli, an opinion that is intensely debated in current emotion research and will be further discussed in Section 3.4 on emotion and attention.

The amygdala also has widespread efferent, partly reciprocal, connections to sensory and motor cortices, but also to the prefrontal cortex including the orbitofrontal cortex, and the anterior cingulate cortex as evidenced by neuroanatomical studies (Barbas & Pandya, 1989; Amaral, Price, Pitkanen, & Carmichael, 1992; Pandya & Yeterian, 1996; Barbas, 2000; Freedman, Insel, & Smith, 2000). Functional connectivity studies also support such a pattern of connections (Zald, Donndelinger, & Pardo, 1998; Schoenbaum, Chiba, & Gallagher, 2000; Gilboa et al., 2004; Kilpatrick, Zald, Pardo, & Cahill, 2006; Stein et al., 2007). The involvement of the anterior cingulate cortex in emotion will be described in the following section.

3.2.3 The anterior cingulate cortex

The anterior cingulate cortex has already been discussed in Chapter 2 as a major part of the executive attention network. However, it also plays a role in emotional processing; see, e.g., Dalgleish (2004) in "The emotional brain" who writes: "Contemporary affective neuroscientists view the ACC as a point of integration of visceral, attentional and emotional information that is crucially involved in the regulation of affect and other forms of top-down control. It has also been suggested that the ACC is a key substrate of conscious emotion experience [...] and of the central representation of autonomic arousal." (p. 587). A widely accepted view divides the ACC in a *dorsal cognitive portion* and a *ventral affective portion* (Devinsky, Morrell, & Vogt, 1995; Bush, Luu, & Posner, 2000). The ventral part comprises the pre- and subgenual ACC (rostral and ventral to the genu of the corpus callosum), thus it has also been referred to as rostral-ventral division. The dorsal part lies more caudally and only includes areas dorsal to the corpus callosum (Vogt, Nimchinsky, Vogt, & Hof, 1995). The non-emotional conflict studies described in Section 2.3.2 mainly conform with this distinction activating the dorsal and not the ventral ACC as can be seen in Figure 2.2. The ventral portion however is routinely activated in studies involving emotional stimuli (for a review see Phan, Wager, Taylor, & Liberzon, 2004). Bush et al. (2000) argued for the ventral affective - dorsal cognitive distinction based on a large review of cognitive and emotional studies. Mohanty et al. (2007) provided recent evidence also showing this differentiation in comparable tasks in the same subjects. They presented the original Stroop task (see Section 2.2), and an “emotional Stroop task” in which emotion words were presented in different colors that participants had to identify (for a detailed discussion of this task see Section 3.4). “Subdivision of the ACC” (ventral - dorsal) was included as a factor yielding a clear interaction of task and ACC portion indicating dorsal ACC involvement for incongruent items in the classic Stroop, and ventral ACC activation for emotional items in the emotional Stroop. The authors concluded that the different subdivisions of the ACC really are differently sensitive to emotional and non-emotional tasks. The distinction is also supported by cytoarchitectonic and connectivity differences between the subdivisions. While the dorsal portion primarily connects to lateral prefrontal cortex, parietal cortex, and premotor and supplementary motor areas, the ventral portion of the ACC is connected to the amygdala, periaqueductal gray, nucleus accumbens, hypothalamus, anterior insula, hippocampus and orbitofrontal cortex (for more information see Vogt et al., 1995; Devinsky et al., 1995).

When examining the literature it is evident that the ventral ACC is activated by a variety of emotional stimuli. Phan, Liberzon, Welsh, Britton, and Taylor (2003) for example presented aversive pictures and found ventral ACC activation. Emotional music (Mitterschiffthaler, Fu, Dalton, Andrew, & Williams, 2007) activates the ACC as well as infant laughing and crying (the authors also report a an interaction with participants gender, Sander, Frome, & Scheich, 2007). For an extensive review see Phan et al. (2004). Interestingly, the ACC is also active in anticipation of negative emotional pictures. Herwig, Abler, Walter, and Erk (2007) presented a cue that predicted the occurrence of either a negative, a positive, or a neutral picture. Areas in the ACC were selectively engaged in anticipation of negative emotional stimuli. The experiment can be criticized as the cues were smileys and frowneys that might themselves be emotional to some extent. However, the authors also replicated the result with abstract cues (Herwig, Baumgartner, et al., 2007).

Lesion data also suggest an important role of the ACC in emotion processing (for evidence from experimental lesions in macaques see Hadland, Rushworth, Gaffan, & Passingham, 2003).

In patients with lesions in different areas of the frontal lobe and the ACC, Hornak et al. (2003) showed that the ventral ACC is involved in identification of emotional voices and faces and experienced changes in subjective emotional states. Similarly, after anterior cingulotomy to treat chronic depression, emotion recognition of dynamic visual emotional stimuli was deteriorated in comparison to depressed and healthy controls (Ridout et al., 2007).

The evidence supporting a role of the ACC in emotion processing is very broad; however, its exact function is not entirely understood yet. It is discussed as part of an emotion regulation network also including the orbitofrontal cortex, inferior frontal gyrus and other prefrontal areas (Ochsner & Gross, 2005; Quirk & Beer, 2006; Stein et al., 2007). Petrovic et al. (2005), e.g., found ACC activation when participants received a placebo that they expected to reduce negative emotion when viewing unpleasant pictures. Also, the ACC is discussed as involved in emotional conflict resolution (see Section 3.4, Etkin et al., 2006), as important for conscious emotional experiences (e.g., Lane et al., 1998), and, related to the latter, as representing bodily changes associated with emotional experience (Dunn, Dalgleish, & Lawrence, 2006). As described earlier, bodily changes serve a critical role in affective processing. An influential idea put forward by Damásio, Tranel, and Damásio (1991), the "somatic marker hypothesis", claims that emotional bodily changes are used to guide decision making, involving also the ACC that encodes emotional states through representation of bodily changes (Dunn et al., 2006). Damásio ascribes a special role in using somatic markers for decision making to the ventromedial prefrontal cortex which will be discussed in the next section.

3.2.4 Other regions involved

First evidence of an influence of the prefrontal cortex in emotional experience and emotional regulation came from the classic case of Phineas Gage whose left prefrontal cortex was destroyed in an accident (Harlow, 1848, 1868). This dramatically changed his behavior to quick expression of anger, impatience, and disrespect. Also, he was unreliable and his employers refused to return him to his previous position. Later investigation of patients with similar lesions in the ventromedial prefrontal cortex (VMPFC) supported the claim that this region is important in decision making in situations of uncertainty (Damásio, Grabowski, Frank, Galaburda, & Damásio, 1994; Damásio, 1994). They showed that these patients were not able to use the subtle emotional values of multiple stimuli in uncertain situations, e.g., in ambiguous card games (Bechara, Damásio, Damásio, & Anderson, 1994). The somatic marker hypothesis (Damásio et al., 1991) explains these results such that somatic markers, physiological reactions like shifts in autonomic nervous system activity, tag emotionally significant events. They then detect and signal subsequent events that have had emotional consequences before. The VMPFC is thought to be involved in the generation of somatic markers when contemplating future response options, not holding a representation of the situation or bioregulatory state directly but being able to reactivate it through triggering appropriate other regions of the brain. Here the ACC is important as one structure that represents emotional bodily changes. In conclusion, the VMPFC seems to be important in social emotional behavior as a structure associating future events with emotional consequences of similar past events, based on representations of emotional bodily states coded in the ACC.

Another important region is the orbitofrontal cortex (OFC), which is also strongly connected to the ventral ACC. It is crucial for learning emotional and motivational values of stimuli (Rolls, 1990, 1996, 1999). Rolls views emotions as states elicited by rewards and punishers, emphasizing the motivational aspect of emotions. He assumes that the OFC works together with the amygdala to develop associations of initially neutral stimuli with primary reinforces such as food, drink, and sex. Neutral stimuli thereby become secondary reinforcers. Rolls showed that neurons in the OFC can detect changes and reversals in the reward value of these learned stimuli.

Davidson also stresses the motivational relevance of emotions in his model of prefrontal emotional functions (Davidson, 1985; Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Davidson, 1995, 1998). Similar to others (e.g., Gray, 1990) he assumes that the core dimensions along which affect is organized are approach and withdrawal and relates the right prefrontal cortex to withdrawal and inhibition, whereas the left prefrontal cortex is related to approach-related appetitive behavior. The prefrontal cortex, thus, sends biasing signals to other brain regions to guide behavior.

Summarizing the evidence on the prefrontal cortex' involvement in emotion, it is apparent that it, together with the ACC, links emotion and cognition, guiding decision making, and linking emotional evaluations to motivation.

Several subcortical regions are also important for emotional processes including the hypothalamus (Teitelbaum & Epstein, 1962) and the basal ganglia (Robbins, Cador, Taylor, & Everitt, 1989). Pell and Leonard (2003), for example, showed the involvement of the basal ganglia in processing the emotional prosody of speech. The next section specifically addresses the question how verbal emotional stimuli such as emotional words and emotional prosody are processed.

3.3 Specifics of verbal emotional stimuli

Humans are amongst the most social of animals. Living in groups, humans have developed complex mechanisms of communicating information. As described above, facial expressions may convey emotional information that others are able to comprehend (for an intercultural perspective see Mandal & Ambady, 2004). Face perception has been extensively investigated, in fact, it is the most frequently used emotional stimulus[3] (Vuilleumier & Pourtois, 2007). Gestures can also communicate emotion (Grosbras & Paus, 2006; Peelen & Downing, 2007). The most powerful tool in communication, however, is language as it enables the exchange of very complex and abstract information. But is it also powerful in signaling emotions? The importance of verbal communication in general suggests that it would be very useful to rapidly detect emotion conveyed in a verbal stimulus. Also, vocal perception is, compared to facial and posture expressions, rather independent of speaker distance and viewing conditions. Indeed, as will be discussed below, it has been shown that emotional cues in prosody[4] are detected very fast. But what about written language? Scripture is much younger, onto- and phylogenetically, than vocal expression. Nevertheless, evidence accrues that even written words may elicit rapid emotional responses. The current section discusses this evidence, which is vital for the present thesis in which the impact of verbal emotional stimuli, visual and auditory, was investigated. First, studies examining the effects of visually presented words are described; a second part focuses on emotional prosody.

3.3.1 Emotional word reading

Only few neuroimaging studies with emotional words have been conducted to date. Nevertheless, activation of the amygdala seems to be a rather consistent finding in such different designs as ink color naming (Isenberg et al., 1999), oddball studies (Strange, Henson, Friston, & Dolan, 2000),

[3]According to web of knowledge (http://apps.isiknowledge.com/) there are 1379 publications on “emotion and face”, 853 on “emotion and language”, “724 on emotion and speech”, 669 on “emotion and verbal”, 444 on “emotion and picture“, 306 on ”emotion and image“, and 72 on ”emotion and gesture“.

[4]Prosody is understood as the information conveyed in a speaker’s voice, independent of the meaning of the words used. It is possible, e.g., to understand anger expressed in a language other than those that the perceiver knows (Schirmer & Kotz, 2006).

valence evaluation (Tabert et al., 2001), or lexical decision (Nakic, Smith, Busis, Vythilingam, & Blair, 2006). These studies investigated negative emotional words. Hamann and Mao (2002), however, could show that the amygdala is also activated to positive emotional word in a passive viewing task. Similarly, Dougal, Phelps, and Davachi (2007) reported amygdala activation for positive and negative words which also predicted subsequent recollection memory. Activation of the amygdala to negative and positive emotional words raises the possibility that arousal, and not valence, is the critical feature engaging the amygdala. Lewis, Critchley, Rotshtein, and Dolan (2007) tested this possibility by directly comparing positive and negative emotional words that were highly variable in the arousal value. The participants' task was to evaluate how well each presented word described the participant himself. They found that the amygdala is mainly sensitive to arousal, not valence, whereas regions in the orbitofrontal cortex differentiated valence, but not arousal. To be fully generalizable this result would require replication with an implicit task, including also neutral words as a comparison. Additionally to the amygdala and the orbitofrontal cortex, the ACC is often activated for emotional words (Osaka, Osaka, Morishita, Kondo, & Fukuyama, 2004; Kuchinke et al., 2005; Nakic et al., 2006; Hirata et al., 2007).

In contrast to the literature on emotional faces (see Section 3.2.2), most researchers hesitate to interpret the amygdala activation for emotional words, other than that the amygdala is involved in emotional word processing. This may be the case as visually presented words are rather "nonbiological" stimuli. Nevertheless, the possibility of rapid emotion detection even from words is often alluded to. Isenberg et al. (1999), for example, formulated: "Activation in the lingual gyrus/parahippocampal gyrus on the left, in our study, may represent modulation by the amygdala of the ventral visual stream for words specifically signifying danger" (p. 10458). As has been argued for emotional faces this implies that the amygdala is activated rapidly and can henceforth modulate cortical processing of the visual stimuli. Such a claim can, of course, not be made on imaging data with poor temporal resolution alone. Nevertheless, there is some informative evidence from patient, EEG, and MEG studies.

Landis (2006) described data from an epileptic patient with intracranial electrodes in the amygdala[5]. When presented emotional and neutral words and pseudowords for very brief intervals (13 ms), the patient was not able to perform a lexical decision task above chance

[5]Together with Stephanie Ortigue the effect could very recently be replicated in another 4 patients. The results are not yet published. Personal communication, June 14th 2008.

level. Still, the amygdala differentially responded to emotional and neutral words already 60 ms poststimulus presentation. This is well before word identification is supposed to take place in the visual word form area in inferior temporal cortex which has been indexed in a posterior N200 between 240 and 300 ms (for studies on word reading see Petersen, Fox, Posner, Mintun, & Raichle, 1988; Kronbichler et al., 2004; Peng, Hu, Liu, Liu, & Ding, 2006; Gaillard, Naccache, et al., 2006; Gaillard, Cul, et al., 2006; Goswami & Ziegler, 2006; Proverbio, Zani, & Adorni, 2008). There is one other investigation of emotional word effects in epilepsy patients with intracranial electrodes (Naccache et al., 2005). They also found effects of subliminally presented words, even when they were masked, however, only in a later time-window (after 350 ms without a mask, and after 800 ms with mask). Clearly, more research is necessary to elucidate this discrepancy. Also, patients may display altered brain responses due to the epilepsy. EEG and MEG studies in healthy participants provide less accurate localization of effects, but can provide hints to the timing of effects nevertheless.

During the last years a considerable amount of EEG data on early and very early effects of emotional words has accumulated (for a review of studies published before 2006 see Kissler, Assadollahi, & Herbert, 2006). Several of these publications found effects around 200 ms poststimulus on the P2 component (Begleiter & Platz, 1969; Begleiter, Projesz, & Garazzo, 1979; Schapkin, Gusev, & Kuhl, 2000; Bernat, Bunce, & Shevrin, 2001; Herbert, Kissler, Junghöfer, Peyk, & Rockstroh, 2006; Kanske & Kotz, 2007). Also, an enhanced posterior negativity between 200 and 300 ms after stimulus onset has been reported (Kissler, Herbert, Peyk, & Junghofer, 2007; Herbert, Junghöfer, & Kissler, 2008). Applying the same design as Landis (2006), Ortigue et al. (2004) found an even earlier effect; negative words modulated the scalp distribution between 100 and 140 ms after word presentation. Also, very recently several reports of emotional word effects on the P1 (80 - 120 ms) were published (Li, Zinbarg, & Paller, 2007; Scott, O'Donnell, Leuthold, & Sereno, 2008; Hooff, Dietz, Sharma, & Bowman, 2008; Taake, Jaspers-Fayer, & Liotti, 2008). Evidence for a role of the amygdala in early emotion detection also comes from an MEG study in which participants passively viewed word pairs consisting of negative, positive, and neutral words (Garolera et al., 2007). They found synchronization in the theta band after presentation of negative words, which was localized to the left amygdala and started at 150 ms poststimulus onset. If these early emotion effects prove to be consistent, they may suggest that emotionality in words can be detected before words are identified in the visual word form area. Bernat et al. (2001) for example argue that, even though words are not biologically prepared[6] as faces, or pictorial stimuli, participants reactions may have been ”based more on learned iconic representations than genuine [...] semantic decoding“ (p. 30). As described above (see Section 3.2.2), the amygdala ”learns” the negative value of abstract line drawings (e.g., of an airplane that is clearly not biologically prepared) when they are paired with aversive electric shocks very fast (in 12 trials). The amygdala subsequently reacts to these abstract line drawings even when the primary visual cortex is destroyed bilaterally, i.e., through information received via a subcortical pathway (Hamm et al., 2003). Emotional words are associated with the negative or positive meaning as often as they are read, from the time on in which reading is acquired. Li et al. (2007), therefore, suggested that the subcortical pathway may “provide a putative anatomical basis” also for emotion detection in word stimuli (p. 31, for a discussion see also Kissler et al., 2006; Li, Paller, & Zinbarg, 2008). The authors, however, point out that, although “it is intriguing that emotional discrimination based on words could also occur so quickly; further research is needed to understand the mechanism” (p. 31). Landis (2006) proposed a variant of that idea. To explain his result of amygdala activation 60 ms after word presentation he proposed that the amygdala is activated through input from extrastriate visual cortex and then modulates visual cortical emotion perception. The model differs in that it does not claim the involvement of a subcortical route to the amygdala, however, the amygdala still perceives relatively crude sensory input and must implement an emotion detection mechanism before “common” visual word identification.

In summary, even though studies on emotional words are rare compared to face and pictorial studies and several open questions remain, there is strong evidence for early emotion detection in words, possibly in the amygdala. The data for emotional prosody processing is even more sketchy, the next section summarizes the available experiments.

3.3.2 Emotional prosody

The sound of a voice is greatly influenced by an individuals affective state. Emotions change physiological parameters such as heart rate, blood flow, and muscle tension which in turn alter

[6]The concept of biological or evolutionary preparedness was originally derived from critique of the premise of equipotentiality. This premise states that stimuli do not differ in how easily they can be associated with an unconditioned stimulus during Pavlovian conditioning. However, cues that, phylogenetically, have been recurrently encountered in threatening situations seem to be more ready, or prepared, for association with unconditioned aversive stimuli (Seligman, 1971).

vocal production. Emotional arousal for example increases laryngeal tension and subglottal pressure, resulting in increased intensity. Scherer (2003b) reviewed investigations on emotional prosody and found the following pattern to be characteristic (see Table 3.1):

	Stress	Anger/Rage	Fear/Panic	Sadness	Joy/Elation	Boredom
Intensity	↑	↑	↑	↓	↑	
F0 floor/mean	↑	↑	↑	↓	↑	
F0 variability		↑		↓	↑	↓
F0 range		↑	↑(↓)	↓	↑	↓
Sentence contours		↓		↓		
High frequency energy		↑	↑	↓	(↑)	
Speech and articulation rate		↑	↑	↓	(↑)	↓

Table 3.1: Acoustic characteristics of emotional prosody based on Johnstone and Scherer (2000); Scherer (2003b)

To infer others affective states it is highly adaptive to pick up these emotional signals from prosody. Humans seem to be able to do so quite rapidly (for an example using an MMN paradigm, also reporting sex differences see Schirmer, Kotz, & Friederici, 2005). However, the amount of studies on the neural basis of emotional prosody processing is still limited. In a model depicting the processes underlying the understanding of emotional prosody Schirmer and Kotz (2006) describe three stages, also explaining hemispheric differences (for a review also see Kotz, Meyer, & Paulmann, 2006). It shall be outlined briefly, for a detailed description see the original article. In a first “sensory processing“ stage, acoustic analysis is mediated by bilateral auditory processing areas in the superior temporal sulcus. Here the left hemisphere has a higher temporal resolution than the right hemisphere. In the second stage emotionally significant cues are integrated. The left hemisphere dominates linguistic, the right hemisphere paralinguistic characteristics. Information is projected from the superior temporal gyrus to the anterior part of the superior temporal sulcus, mainly in the right hemisphere. The third ”cognition“ stage incorporates evaluative judgements and semantic processes involving the right inferior frontal gyrus and the orbitofrontal cortex. The model explains well the often observed right lateralized activations found for emotional prosody (see, e.g., Buchanan et al., 2000, but also Kotz et al., 2003). It does so by focusing on the regions directly involved in auditory processing, however, the authors also claim involvement of top-down and bottom-up processes. Such, the amygdala may detect emotion early on and modulate the described processing stream.

Amygdala activation by emotional prosody has been reported in a few studies (Phillips et al., 1998; Quadflieg, Mohr, Mentzel, Miltner, & Straube, 2008). Sander et al. (2005) also found that emotional prosody specific activation in the amygdala was independent of whether it was presented to the attended or the unattended ear, suggesting that it is somewhat automatic. In a recent experiment Beaucousin et al. (2007) presented neutral and emotional sentences spoken either by actors or by text-to-speech software that lacked emotional prosody. The amygdala showed activity for emotional prosody. However, there are also studies that failed to find amygdala activation (Royet et al., 2000; Pourtois, Gelder, Bol, & Crommelinck, 2005) or even found a reduction in amygdala activation to emotional prosody (Morris, Scott, & Dolan, 1999).

There is some patient data that also supports a crucial role of the amygdala in emotional prosody. Scott et al. (1997) for example found deteriorated perception of vocal affect in patients with amygdala lesions. Similar results were observed by Sprengelmeyer et al. (1999) and for vocal emotional memory by Brierley, Medford, Shaw, and David (2004). Again, the picture is blurred by other studies reporting no effect after amygdala lesions (Anderson & Phelps, 1998; Adolphs & Tranel, 1999) or an effect in some, but not all patients (Fowler et al., 2006). It is therefore a question still to be investigated, how reliable the amygdala can be activated in response to emotional prosody (for reviews see also Adolphs, 2002; Zald, 2003). As described above (see Section 3.2.2), for audition, a subcortical route to the amygdala has been demonstrated in primates (Campeau & Davis, 1995; Armony et al., 1997; Doron & Ledoux, 1999). Also, emotional vocal signals do not lack biological preparedness (as compared to visually presented words). As preferential processing of emotional prosody has been demonstrated (see for example Grandjean, Sander, Lucas, Scherer, and Vuilleumier (2008) where emotional prosody overrode neglect) it is not out of question, that the amygdala rapidly, and potentially automatically (Sander et al., 2005), detects emotional prosodic cues.

As depicted in this section on the specifics of emotional verbal stimuli, the data is not yet entirely clear, motivating further investigation of the effect of emotional words and prosody. The current thesis is based on the evidence for rapid detection of emotion from verbal stimuli. It implicitly tests this question by focusing on the influence of rapid emotional effects on attentional mechanisms which is the main target of the thesis. Therefore, as attention has been introduced in the previous Chapter 2, and the relevant effects of emotion were outlined in the first sections of the current Chapter 3, the discussion now turns to previous research on emotional influences on attention.

3.4 An emotional influence on attention

Discovering emotionally salient cues in the environment plays a fundamental role in evolutionary adaptation. To have survival value, monitoring of potentially salient cues with emotional valence should be rapid and appropriate (LeDoux, 1995). Of course, an evolutionary advantage also critically depends on rapid and appropriate selection of a subsequent behavioral response. The question how emotion influences attentional processes is therefore a necessary one and has been the target of many investigations. There are multiple approaches to study the interaction of emotion and attention. A large body of research examines the attentional effects of emotional stimuli indirectly. By studying the processing of attended and unattended emotional stimuli it is possible to make conclusions about the saliency of emotional stimuli to trigger bottom-up attentional processes. Other studies try to show that performance on parallel cognitive tasks is impaired by emotional distractors, inferring that attentional "resources" are captured by the emotional stimuli. A second approach directly studies the effect of emotional stimuli on attentional networks. These approaches will be discussed in the current section, with an emphasis on the latter. As the present thesis aimed at directly investigating the effects of emotion on executive attention, the indirect studies will only be briefly summarized.

3.4.1 Indirect studies of emotion attention interactions

Studies examining emotion detection under different attentional conditions mainly focus on the amygdala as the structure that implements emotional salience processing and somewhat bottom-up like attentional effects. The main idea has already been discussed in Section 3.2.2 on the amygdala. Via a subcortical route the amygdala may receive crude sensory information that enables it to detect emotional signals even when the stimuli are presented subliminally or can not be processed through visual cortices in lesion patients (Whalen, Rauch, et al., 1998; Morris et al., 1998; Hamm et al., 2003). The results are less coherent in studies in which attention is manipulated. Vuilleumier, Armony, Driver, and Dolan (2001) presented emotional and neutral faces, as well as pictures of different houses to participants who were to decide whether two houses or two faces were the same or different. Critically, there were always two houses and two faces present, only that one stimulus pair was attended to, the other was not. Activation in the amygdala was sensitive to emotional faces independent of whether the faces were attended or not. Vuilleumier et al. (2001) interpreted this as evidence for automatic detection of emotional stimuli. In contrast, Pessoa, McKenna, Gutierrez, and Ungerleider (2002) found no amygdala activation to emotional stimuli when participants indicated whether two peripherally presented bars were in the same orientation or not. The amygdala was, however, activated when the task was to decide the gender of the centrally presented emotional face. Several studies followed up on these results, but the effect of attention on emotion detection in the amygdala is not yet clear (Anderson, Christoff, Panitz, Rosa, & Gabrieli, 2003; Sander et al., 2005; Pessoa, Padmala, & Morland, 2005; Mitchell et al., 2006; Silvert et al., 2007; Bishop, Jenkins, & Lawrence, 2007, for reviews see also Vuilleumier, 2005; Taylor & Fragopanagos, 2005). The results may, however, be reconciled when amygdala activation can be investigated with higher spatial resolution. Some of the studies listed above hint at such a possibility, i.e., some nuclei in the amygdala (mainly the lateral nucleus that is an input area) are activated independent of attentional modulation, whereas other regions (e.g., the central nucleus which is an output area) are not independent of attention to the emotional stimuli.

The finding of impaired performance on concurrent tasks, when emotional stimuli are presented as distractors also argues for some automatic processing of emotional stimuli, including some demand on ”attentional resources“ (for examples see Hartikainen, Ogawa, & Knight, 2000; Gronau, Cohen, & Ben-Shakhar, 2003; Attar, Andersen, & Müller, 2006; Okon-Singer, Tzelgov, & Henik, 2007). Müller, Andersen, and Keil (2007) used steady-state visual evoked potentials (SSVEP) which allow continuous measurement of the time-course of competition between different presented stimuli. Participants' target detection task involved flickering squares which elicited the SSVEPs. In the background emotional and neutral images were displayed. The presence of emotional compared to neutral images led to decreased target detection of the foreground squares, as well as a decreased SSVEP amplitude for the squares between 400 and 1000 ms poststimulus onset over occipital electrodes. The authors interpretation of the results was that emotional images withdraw processing resources from the detection task. Another elegant paradigm showing that emotional stimuli distract, or require attentional resources is the attentional blink task. In this task a second target stimulus (T2) is detected less accurately when succeeding an earlier target (T1) in a row of rapidly presented stimuli. Metaphorically attention is “blinking” after the first target, missing the second (Chun & Potter, 1995; Luck, Vogel, & Shapiro, 1996; Potter, Chun, Banks, & Muckenhoupt, 1998). Ihssen and Keil (2004) reported an increased attentional blink, i.e., decreased accuracy regarding T2, after presentation of a high arousing emotional word as T1. This suggests that processing of the emotional word required more attentional resources which were consequently not available for processing T2. Conversely, the authors and others (Anderson & Phelps, 2001; Keil & Ihssen, 2004; Anderson, 2005) also presented emotional words at the position of T2. This manipulation reduced the attentional blink; affectively arousing information seems therefore to be selected preferentially, or to attract attention more than neutral stimuli. This has also been shown through interactions of emotion with the attentional networks described in Chapter 2. The evidence for alerting and orienting of attention is relatively strong, for executive attention however, only very few studies with inconsistent results have been conducted so far. The next two sections briefly address the effects of emotion on alerting, orienting, and executive attention, with an emphasis on the latter.

3.4.2 Direct studies of emotion attention interactions

Evidence for an *alerting* effect of emotional stimuli comes from studies in animals and in humans. Stock, Stumpf, and Schlör (1979) stimulated different brain regions in cats and recorded peripheral physiological as well as behavioral measures. As has been shown by others, they report increased alertness after stimulation of the locus coeruleus (see also Section 2.1 Aston-Jones & Cohen, 2005). Interestingly, stimulation of the amygdala also increased arterial pressure and heart rate and a behavioral alerting reaction (for results in rats see Sanford, Tejani-Butt, Ross, & Morrison, 1995). As has been shown, the amygdala projects to the locus coeruleus which may be the basis of this modulatory role of the amygdala in alertness regulation (Hamm, Weike, & Melzig, 2006). Liddell et al. (2005) demonstrated that fearful faces elicit activity in the amygdala and the locus coeruleus even when presented subliminally to participants. The authors interpreted this finding such that crude sensory input from the subcortical pathway to the amygdala may allow for sufficient appraisal of fear signals to innervate the locus coeruleus and conclude that this may represent an evolutionary adaptive neural alarm system for "rapid alerting". To date there are no studies that manipulated alerting through cues, comparing the effect of neutral and emotional cues on subsequent RTs.

As *orienting of attention* has been extensively investigated with the spatial cueing paradigm (see Section 2.1, Posner, 1980) an emotional modulation of orienting has also mainly been studied with this design. Researchers varied the emotional valence of spatially informative cue stimuli to see how processing of subsequent target stimuli would be influenced. Different types of cue stimuli were used for this purpose, including conditioned stimuli (Stormark & Hugdahl, 1996, 1997; Stormark, Hugdahl, & Posner, 1999; Armony & Dolan, 2002; Koster, Crombez, Damme, Verschuere, & Houwer, 2004; Damme et al., 2004), faces (Pourtois, Thut, Peralta, Michel, & Vuilleumier, 2005; Pourtois & Vuilleumier, 2006), emotional words (Stormark, Nordby, & Hugdahl, 1995; Leland & Pineda, 2006), and emotional prosody (Brosch, Grandjean, Sander, & Scherer, 2008). The common finding is that target detection is sped after valid emotional stimuli, and prolonged after invalid emotional stimuli, suggesting that attention is oriented faster to emotional stimuli, and that participants need longer to orient attention away from an emotional stimulus. Stormark and others (Stormark et al., 1995, 1999; Pourtois & Vuilleumier, 2006) showed that the P1 and N1 component of the visual evoked potential elicited by the target stimulus are also sensitive to the emotional valence of the cue stimuli. This result is corroborated by an fMRI study finding enhanced extrastriate activity when using noise conditioned visual stimuli as cues. The amygdala, and the fronto-parietal orienting network were preferentially activated in response to conditioned stimuli. A recent study could even show that a modulation of spatial attention through emotional cue stimuli works cross-modally, when emotional prosody predicts the location of a subsequent visual target (Brosch, Grandjean, et al., 2008). The evidence reported here strongly supports the claim that emotional stimuli orient attention. There is less clarity regarding an influence of emotion on *executive control of attention* which will be discussed in the next section.

3.4.3 Emotion and executive attention

As described in Chapter 2, executive control of attention enables coherent, goal-directed behavior even in the presence of distracting stimuli that elicit conflicting action tendencies. Common experimental paradigms testing this function are the Stroop, flanker, and Simon task in which some form of conflict is present. By comparing reactions to incongruent and congruent stimulus situations an index of executive control can be obtained (conflict score). As there are only very few studies testing the influence of emotion on executive attention these will be described in some more detail.

Kuhl and Kazén (1999) used a variant of the Stroop paradigm. They presented incongruent (e.g., the word "red“ in green ink color) and neutral (a row of "X“) stimuli. There were always two of these stimuli presented one after the other constituting one trial. Before onset of the first of the two Stroop stimuli, a word of negative, neutral, or positive valence was presented. The conflict score of the first Stroop task was numerically reduced after both, negative and positive words, however, only significantly so for the positive condition. In the second Stroop task in contrast, no significant effect was observed on the conflict score, but on the RTs in the incongruent condition. Here, however, RTs were longer after positive compared to neutral and negative words. No significant effects were observed on error rates. The authors also reported a second experiment in which self-generated emotional words were used. Also, there was an additional condition in which not two subsequent, but only one single Stroop task was presented. Again, the conflict score of the first of two Stroop stimuli was reduced, but only significantly after a positive emotional word. For the second and the single Stroop task some numerical, but not significant modulations were found. The authors explain the (occasional) finding of enhanced executive control after emotional words as ”volitional facilitation“. According to their model emotional stimuli[7] activate ”intention memory“ which enables better executive control.

In a second series of studies (Kazén & Kuhl, 2005), the authors compare the effect in different populations, and with different types of emotional words, the idea being that need-relevant words are especially suited to activate intention memory and thus influence executive attentional control. There is some support for this claim in the data, e.g., achievement related words are especially effective in unemployed participants, but the overall data pattern is very complex leaving a clear conclusion open.

Instead of emotional words, Dennis et al. (Dennis, Chen, & McCandliss, 2007; Dennis & Chen, 2007a, 2007b) presented pictures of emotional faces shortly before an arrow flanker task. The flanker task was presented as part of the attention network test (ANT; Fan, McCandliss, Sommer, Raz, & Posner, 2002), which also yields measures of alerting and orienting. Thus, the sequence of events in a trial consisted of (1) an emotional face, followed by (2) an alerting or orienting cue, and (3) a row of flanker stimuli. This procedure was applied to participants either high or low in anxiety. The results of the three experiments vary. Fearful faces enhanced executive control, but only in high anxiety participants in one study (Dennis & Chen, 2007b), in another study however (Dennis et al., 2007), this enhancement was not observed; in contrast, a decrement in executive attention, but only in low anxiety participants, was present. A third study yielded an enhancement of executive attention following fearful faces for all participants (Dennis & Chen, 2007a). In two of the studies (Dennis & Chen, 2007a, 2007b) event-related potentials elicited by the faces were measured. The size of early potentials (P1, P2, N2) interacted with

[7] Even though the authors only found significant effects for positive words, they do not exclude the possibility that negative emotional stimuli may also reduce conflict.

anxiety level and conflict scores producing a complex pattern of partly inconsistent relations. It should be mentioned though, that the three studies may not be well comparable. Despite the same experimental procedure (face, cue, flanker) the experiments differed in (1) whether a neutral face control condition was present or not, (2) whether a neutral non-face control condition was presented, (3) which electrodes were included in the analysis, and (4) the exact timing of the events in a trial. Different results may, thus, be due to these varying experimental settings. Nevertheless, if emotion truly modulates executive attention, such an effect should be reliably observable in different experimental settings.

A potential caveat of the described studies may be that the target stimuli themselves were not emotional. Instead, unrelated emotional stimuli were presented before the target stimulus appeared, i.e., the stimulus that was behaviorally relevant. However, why should the emotionality of a stimulus influence processing of conflict elicited by completely unrelated other stimuli? As described above, emotions may guide executive control by rapid stimulus evaluation according to current goals etc., henceforth, the effect may be restricted to that particular stimulus. Investigation of the question whether emotion modulates executive attention may require a design in which the stimuli eliciting conflict are emotional themselves.

The present thesis, therefore, aimed at clarifying the effect of emotion on executive attention and at replicating the results with different experimental designs and in different modalities. Additionally, the neural basis of the effect was investigated. There are several related paradigms that are of interest, testing the effects of motivation, or because they provide some hints in regard to the neural basis of an emotion executive attention interaction[8].

Motivation and executive attention. Emotion and motivation are deeply integrated. Appropriate evaluation of environmental emotional stimuli regarding present needs and goals yields response and motivational tendencies. Studies investigating an influence of motivation on executive control of attention may therefore be informative for the present thesis as well. In experimental settings direct manipulation of motivation is predominantly achieved through monetary incentives. Such a reinforcement was used by Seifert, Naumann, Hewig, Hagemann, and Bartussek (2006) who applied a version of the flanker task with a cue signaling whether

[8]There are some experimental designs that are neglected here because they were too far from the current question of interest. These are a few studies assessing an interaction of mood and executive attention, with partly contradicting results (e.g., Phillips, Bull, Adams, & Fraser, 2002), studies using the antisaccade task in different motivational scenarios (e.g., Jazbec, McClure, Hardin, Pine, & Ernst, 2005), and a couple of reports on forms of task-switching experiments (e.g., Dreisbach & Goschke, 2004).

the current trial was a loose, win, or no incentive trial. The conflict effect in the error rates was reduced in win trials, compared to no incentive, but not to loose trials which were intermediate. This pattern was also present in LRPs, however, no effect was found on RTs, and a conflict N200 was not elicited. The data offer partial support for a motivational modulation of executive attention, but replication and further research clarifying the lack of a conflict N200 is clearly needed. The next two paragraphs describe research on some form of emotional conflict that inform about potential neural bases for emotional modulation of executive attention.

Emotional conflict. A widely used paradigm is the emotional Stroop task (Williams, Mathews, & MacLeod, 1996), in which, as in the original Stroop, words are presented in different ink color that participants are to identify. Instead of color words (e.g., "blue"), however, emotional and neutral words are presented. This design has been successfully applied in clinical populations to investigate distraction by emotion (for evidence in schizotypy, bipolar, and depressed patients see, e.g., Mohanty et al., 2005; Malhi, Lagopoulos, Sachdev, Ivanovski, & Shnier, 2005; Mitterschiffthaler et al., 2008). Yet, in contrast to the original Stroop, the emotional Stroop design elicits no conflict because an emotional word is not associated with a specific color (that could be different from the ink color) as a color word is (Algom, Chajut, & Lev, 2004)[9]. Furthermore, an effect is only present in blocked designs (Chajut, Lev, & Algom, 2005; Hooff et al., 2008). McKenna and Sharma (2004) and Phaf and Kan (2007) showed that this may be the case because emotional words do not affect color naming in the current trial at all, but at best in the subsequent trial, canceling out any effects in randomized non-blocked presentation. Also, the effects have been mainly restricted to clinical populations and are not present in healthy controls (Williams et al., 1996) or habituate rapidly (Compton, 2003). Larsen, Mercer, and Balota (2006) very critically observed in an extensive review on the words used in published emotional Stroop studies that response slowing in the emotional Stroop task may be due to the emotional words used being lower in frequency of usage, longer in length, and having smaller orthographic neighborhood. Nevertheless, when stimuli were presented in blocks and emotional words may have some distractor like effect in later trials that requires inhibition, activation in the ventral ACC has been found when emotional and neutral trials were compared (often, however,

[9]The attentive reader will now notice that the current paragraph should be better included in Section 3.4.1 on indirect effects of emotion (such as distraction). The reason for its actual position is that the emotional Stroop is often discussed as emotional conflict task (Dalgleish, 2005).

in the absence of any behavioral effects, Whalen, Bush, et al., 1998, for other references see Table 2.1 on p.24).

A different design has been proposed by Etkin et al. (2006) and Haas et al. (2006); to date there are three more publications with that design (Haas et al., 2007; Egner et al., 2008 also applied fMRI, Xiaokun & Xiaolin, 2007 is a behavioral study). They presented emotional faces with emotional words superimposed on them. Participants evaluated the valence of the face or the word. Conflict was elicited when face and word were of different valence (e.g., a positive word superimposed on a negative face). In contrast to the emotional Stroop task, this design allows assessment of conflict in the classic definition, only that conflict exists between opposing emotions. Consequently, in the published studies, a reliable RT (but not accuracy) effect could be observed, with longer RTs in incongruent than congruent trials. Interestingly, again the ventral ACC which is involved in emotion processing and emotion regulation (see Section 3.2.3), was also involved in the processing of emotional conflict. This allows the conclusion, that not only the dorsal portion of the ACC is sensitive to conflict, but also the ventral part, when emotional stimuli are present (see Table 2.1 on p. 24). This pattern is illustrated in Figure 2.2 on p. 22 in which ACC activations of the emotional conflict and Stroop studies are displayed[10].

Neural basis. The evidence described here and in Sections 2.3.2 and 3.2.3 on the role of the ACC in conflict and emotional processing suggests that the ACC may also modulate emotional and motivational influences on executive control of attention. Some neuroanatomical data support this view. The ventral and the dorsal portion of the ACC share strong interconnections, and also connect to brain regions discussed for higher cognitive functions and emotions including parietal and lateral prefrontal cortices, as well as the amygdala and the orbitofrontal cortex (Stein et al., 2007; Banks, Eddy, Angstadt, Nathan, & Phan, 2007; Margulies et al., 2007).

Interestingly, the ACC also contains von Economo neurons (VEN) that are not found in any other brain region except for the frontoinsular cortex (Economo & Koskinas, 1925; Nimchinsky et al., 1999). They are only present in humans and to lesser extent in the great apes (however, recently there has also been a report in whales, Hof & Gucht, 2007). VEN are not present at birth, but develop, mainly up to the age of four years (Allman, Watson, Tetreault, & Hakeem, 2005), a time range in which large advancements in attention and emotion regulation take place

[10] The study by Egner et al. (2008) was published in June 2008, just before the present thesis was printed, and could not be included in the Figure.

(Gerardi-Caulton, 2000; Rothbart, Ellis, Rueda, & Posner, 2003; Rueda, Posner, & Rothbart, 2005). Allman, Hakeem, Erwin, Nimchinsky, and Hof (2001) pointed out that the emergence of the first VEN four months postnatally coincides with the development of focused attention and emotional expression such as spontaneous smile, visual object tracking and reaching for objects. Because of the described features of VEN in the ACC, Allman et al. (2001) called the ACC the ”interface between emotion and cognition“ (p. 107).

The last point to be mentioned concerns the role of neuro-transmitters. Executive attention has been linked to the dopamine system. Servan-Schreiber, Carter, Bruno, and Cohen (1998) for example observed increased conflict accuracy in a flanker task following D-amphetamine application which strongly enhances dopamine transmission (see also Section 4.1 for more information). As the mesolimbic dopamine system also plays an important role in motivation (especially in reward, Berridge & Robinson, 1998) interactions between dopaminergic processes of motivation and attention may account for emotional and motivational modulation of executive control of attention. Potts, Martin, Burton, and Montague (2006) elaborated on this idea, proposing that the dopamine system input to the medial frontal cortex, including the ACC, supports the identification of task-relevant perceptual representations, i.e., ”reward prediction properties, provide a “gate” through which information gains access to a limited-capacity system” (p. 1112). These data support a positive influence, at least of positive emotion on executive attention.

3.5 Summary

This chapter showed that the brain detects emotion in stimuli very rapidly. It even detects emotion in subliminally presented stimuli, and when the primary sensory cortex is destroyed and conscious perception is disabled. The amygdala seems to be critically involved in these processes providing an early “labeling” of incoming emotional stimuli. Through widespread connections the amygdala can modulate sensory processing of emotional stimuli, but also sends signals to medial frontal, anterior cingulate and orbitofrontal cortices. These give rise to conscious emotion perception, regulate emotions, and provide motivational value. Even though emotion research focused on face stimuli, evidence accrues that verbal emotional stimuli also possess particular salience. They do, for example, speed orienting of attention, or influence the attentional blink. The effects of emotional stimuli on executive attention are not yet clear.

Some contradictions in earlier studies may be due to specifics in the experimental designs; this motivated the use of a different paradigm in the present dissertation. In regard to the neural basis of an emotional modulation of executive attention, neuroimaging and other data strongly suggest the involvement of the ACC. Before the hypotheses for the present investigation are formulated, interindividual differences that may be related will be briefly discussed in the next chapter.

Chapter 4

Interindividual differences

The previous chapter described research on the organisms reaction to emotional stimuli, including modulation of attentional processes. However, individuals do not exhibit identical reactions to even the same emotional stimuli when (1) the reaction is observed at different points in time or when (2) reactions of different individuals are compared. Also, individuals differ in how well they are able to control attention. The current chapter briefly focuses on these interindividual differences. Section 4.1 describes the temperament trait effortful control that is related to executive control of attention. Section 4.2 reviews literature on the emotional states of anxiety and depression that have been found to explain some of the interindividual reaction patterns to emotional stimuli.

4.1 Temperamental differences in effortful control affect executive attention

Effortful control describes the individual's ability for self-regulation (Rothbart, 2007). More specifically it has been defined as the "ability to choose a course of action under conditions of conflict, to plan for the future, and to detect errors" (p. 207, Rothbart, 2007). The concept emerged from, and has mainly been applied in developmental research involving psychometric and laboratory studies (Rothbart & Bates, 2006). Effortful control can also be measured reliably in adults with the adult temperament questionnaire (ATQ, see Section 6.3 Rothbart, Ahadi, & Evans, 2000; Evans & Rothbart, 2007). Example items from the questionnaire are: "I usually finish doing things before they are actually due." "When I see an attractive item in a store, it's usually very hard for me to resist buying it." "When trying to study something, I have difficulty tuning out background noise and concentrating."

The relation of effortful control and executive attention has been extensively studied. Participants high in effortful control commonly exhibit better performance in conflict tasks (Gerardi-Caulton, 2000; Rothbart et al., 2003). Heritability of effortful control (Goldsmith, Lemery, Buss, & Campos, 1999) and of executive attention (Fan, Wu, Fossella, & Posner, 2001) has also been shown. Rueda, Rothbart, et al. (2005), therefore, investigated the dopamine related DAT1 gene which is among other dopamine genes related to executive attention (Fossella et al., 2002; Fan, Fossella, et al., 2003; Diamond, Briand, Fossella, & Gehlbach, 2004; Blasi et al., 2005). They found that the long form of the DAT1 gene was associated with higher effortful control, better conflict scores, and a reliable conflict N200 that children with the mixed allele did not show. This strong evidence suggests that temperamental effortful control can explain interindividual differences in executive attention.

There is also data that hints at a role of effortful control in emotion processing. Kochanska, Murray, and Harlan (2000) found that effortful control measures at 22 months of age was associated with the ability to regulate anger, and predicted anger and joy regulation at 33 months of age. A positive relation of effortful control has also been reported by several other groups (Salmon & Pereira, 2002; Valiente, Lemery-Chalfant, & Reiser, 2007; Carlson & Wang, 2007, for a review see Spinrad, Eisenberg, & Gaertner, 2007). In addition, effortful control is related to several other measures including delay of gratification, the development of conscience, the development of empathy, and lower levels of psychopathology and maladjustment (White et al., 1994; Krueger, Caspi, Moffitt, White, & Stouthamer-Loeber, 1996; Kochanska, 1997; Eisenberg, 2000; Kochanska et al., 2000). In fact, effortful control correlates negatively with subclinical depression and anxiety (Moriya & Tanno, 2008). The next section elaborates on these emotional states. Concluding the section on effortful control, the association of the temperament trait with executive attention is well established. Its relation to emotion regulation and emotional states make it a likely candidate, to mediate an influence of emotion on executive control of attention.

4.2 Emotional states of anxiety and depression

Emotional states strongly modulate the perception of emotional stimuli. This is most easily observable in patients with specific phobia for which the anxiety eliciting stimuli are known. Spider phobics, for example, will detect and be distracted by spiders much faster and stronger than non-phobic participants (Mühlberger, Wiedemann, Herrmann, & Pauli, 2006; Gerdes, Alpers, & Pauli, 2008). But also generalized anxiety disorder (Bradley, Mogg, White, Groom, & Bono, 1999) and depression (Mitterschiffthaler et al., 2008) affect processing of mainly negative emotional stimuli. Interestingly, these effects can not only be observed in clinical, but also in subclinical anxiety and depression, i.e., different anxiety levels in healthy participants can explain differences in processing of emotional stimuli (Scott, Mogg, & Bradley, 2001; Mercado, Carretié, Tapia, & Gómez-Jarabo, 2006; Li et al., 2008).

The neural basis of the heightened sensitivity to emotional stimuli in anxiety and depression includes altered processing in emotion relevant brain regions such as the amygdala and the ventral ACC. In depression, amygdala activation to negative emotional stimuli is increased in faces (Lee et al., 2007) and words (Siegle, Thompson, Carter, Steinhauer, & Thase, 2007; Lee et al., 2007). This effect is even present when the presentation of negative emotional stimuli is anticipated, but no stimuli are actually presented (Abler, Erk, Herwig, & Walter, 2007). For the expectation of positive stimuli this was not found. In contrast, activation of the ventral ACC can be reduced in depression (Drevets et al., 1997). Volume changes in the amygdala and ventral ACC in depression have also been observed (Pezawas et al., 2005, for reviews about the neural basis of depression see Drevets, 2001 and Kalia, 2005).

Similar effects have been found for anxiety affecting the amygdala response (Bishop et al., 2004; Most, Chun, Johnson, & Kiehl, 2006, for a review see Bishop, 2007). The speed of this altered negative emotion processing has been documented through early effects in the ERP response (e.g., P1) and to subliminally presented pictures (Mercado et al., 2006), faces (Bar-Haim, Lamy, & Glickman, 2005) and words (Weinstein, 1995; Li et al., 2007, 2008). There are also several studies yielding insight into the nature of these differences. Participants scoring high in anxiety and depression seem to faster detect negative emotional stimuli, orient attention to the stimuli, and experience difficulties in disengaging from them (Bradley et al., 1999; Mogg & Bradley, 1999; Mogg, Millar, & Bradley, 2000; Fox, Russo, Bowles, & Dutton, 2001; Fox, Russo, & Dutton, 2002; Mogg, Philippot, & Bradley, 2004; Garner, Mogg, & Bradley, 2006; Mogg, Garner, & Bradley, 2007, for an excellent review see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & IJzendoorn, 2007). Section 3.4.3, already described impaired or affected use of emotional and motivational cues for executive control in anxiety and depression. In conclusion, emotional reactivity seems to strongly depend on individual affective states, as evidenced in behavioral and neural measures.

4.3 Summary

In summary, temperamental effortful control is associated with efficient processing of conflict, but also regulation of emotion. Altered processing of emotional stimuli in anxiety and depression indicate some problems in detecting the appropriate relevance of the stimuli in a given situation. This fits well with the pattern of hyper- and hypoactivation in amygdala and ACC. Therefore the heightened sensitivity for negative stimuli and anxiety and depression, and the negative correlation of regulatory processing (effortful control) and depression and anxiety suggest less appropriate evaluation of emotional stimuli regarding the organisms goals in these emotional states. The supportive role emotion my have in guiding executive control of attention may therefore be affected by interindividual differences in effortful control, depression, and anxiety. Therefore, in the present experiments, effortful control, depression, and anxiety was assessed and correlated to the measures investigated. Additionally, the stress state of the participants was measured. For stress no hypotheses were generated, hence, it may serve as a useful control in assessing the specific effects of the emotional states of depression and anxiety.

Chapter 5

Questions and hypotheses

The main question of the present dissertation concerns the interrelation of emotional and executive attentional processes. Is control of attention different when reacting to emotional as compared to neutral stimuli? This question is still in need of clarification. Previous studies either investigated the influence of an accessory response-unrelated emotional stimulus on executive attention, or aimed at a different question, namely how conflict between different emotional stimuli is processed. The other open questions entwine around this major one. Hypotheses, based on the evidence portrayed in the previous chapters are generated.

1. *Does emotion affect attentional control?* Theoretical accounts of emotion and attention allow formulation of the hypothesis that executive control of attention may be facilitated when reacting to emotional stimuli. This should be evident in reduced response times to conflict in emotional stimuli. Effects on error rates should point in the same direction if task difficulty is high enough to yield sufficient variability in the data. The present thesis tests this question with an emotional variant of the flanker task.

2. *What about positive emotion?* Positive and negative emotional stimuli both signal elevated relevance. The prevalent view that negative emotional stimuli are more salient is questioned by recent meta-analyses and studies showing that effects can be obtained with positive stimuli when they are carefully controlled. Therefore, it may be hypothesized that positive, as negative emotional stimuli, affect attentional control mechanisms. This question is tested by using stimuli that participants had previously evaluated as pleasant or unpleasant.

3. *Emotion in words?* Even though emotion research has focused on emotional faces, there is a growing body of evidence suggesting that emotional words are salient as well. The experiments reported here test this question. To establish the salience of the specific emotional words used, before applying them to the main question, their effects on other attentional functions were tested.

4. *Temporal dynamics?* Conflict is detected and processed very fast as indexed in an amplitude increase for conflict in the N200. Emotional modulation of the conflict N200 would demonstrate the rapid nature of such an emotion executive attention interaction. It is hypothesized that behavioral facilitation of conflict processing through emotion should be accompanied by an increase in the conflict N200 amplitude.

5. *Correlates in the brain?* The dorsal ACC is well-established as being involved in conflict processing. However, recent evidence suggests that the ventral ACC is sensitive to conflict as well when emotional stimuli are present. Modulation of attentional control by emotion may therefore be based on additional involvement of the ventral ACC for conflict processing. Conflict activation in the dorsal ACC should be independent of emotion, whereas activity in the amygdala should be sensitive to emotion.

6. *Generalizable?* If emotion modulates executive attention, the effect should be present in different forms of conflict. Application of different conflict paradigms should, therefore, yield comparable results. This was tested by replicating the flanker experiments with an emotional variant of a Simon task.

7. *An effect in audition?* Do the effects also generalize to a different modality? Are there specific effects when presenting stimuli auditorily with additional prosodic information? These questions were investigated by having actors speak the words in affectively congruent intonation, and presenting the recordings instead of the visual word forms, in the Simon task.

8. *What about interindividual differences?* The last question addresses interindividual differences in an emotional modulation of executive attention. It is hypothesized that participants high in subclinical depression and anxiety, and low in temperamental effortful control have difficulty in appropriate evaluation of emotional stimuli leading to a less beneficial effect on attentional control.

Part II

Experiments

Chapter 6

General methods

As the experimental parameters for EEG and fMRI recordings, data processing, and statistical analysis are largely identical for the experiments in this dissertation, they will be described conjointly in the current chapter. Section 6.1 includes the specifics for the EEG experiments and Section 6.2 details the fMRI recording and analysis. Also, participants of all experiments filled out the same questionnaires, which are described in Section 6.3. Table 6.1 summarizes methods, materials, and presentation modality used in all EEG and fMRI experiments.

	Modality		Material		Method	
Experiment	Visual	Auditory	Negative	Positive	EEG	fMRI
1	X		X		X	
2	X			X	X	
3	X		X			X
4		X	X		X	
5		X		X	X	
6		X	X			X

Table 6.1: Summary of methods, valence of word materials, and presentation modality in experiments 1 through 6.

6.1 EEG experiments

EEG measurement. Ag-AgCl electrodes were used to record the EEG from 59 scalp positions according to the international 10-20 system (see Figure 6.1; American Electroencephalographic Society, 1991; Jasper, 1958). Vertical eye movements were registered with two electrodes positioned above and below the right eye. The horizontal electrooculogram was recorded with lateral electrodes from both eyes. The ground electrode was located on the sternum. Data were referenced to the left mastoid while the right mastoid was actively recorded. Impedances were kept below 5 kΩ for all recordings. Brain vision and the corresponding amplifier brainamps were used for experiments 1, 2, and 5. In experiment 4 refa amplifiers and xrefa recording software were used. The sampling rate was 500 Hz. An anti-alias filter was applied online with 250 Hz for brainamps amplifiers and 135 Hz for refa amplifiers.

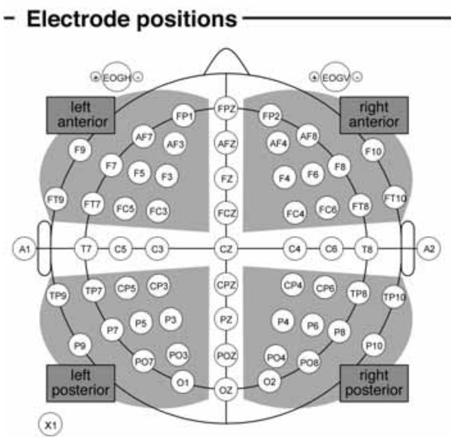

Figure 6.1: Electrode positions and clustering of electrodes into regions of interest for the two-level topographical factors hemisphere (left, right) and region (anterior, posterior). The 59 scalp electrodes are numbered in rows, odd numbers refer to the left, even numbers to the right hemisphere. Letters represent cortical regions in the vicinity of the channels; F frontal, T temporal, C central, P parietal, O occipital. Additional electrodes are A1 and A2, left and right mastoid; X1 ground electrode on sternum; bipolar vertical EOGV and horizontal EOGH electrooculogram.

EEG data processing. While data recorded with xrefa were already in a compressed EEP riff format, the data recorded with brain vision professional recorder software were first converted into this format. To remove slow drifts, a 2 Hz highpass filter was applied in the auditory EEG experiments. As the data in the visual EEG experiments was free of slow drifts no filtering was applied. Further filtering was only applied for graphical display (14 Hz lowpass filter). Data were re-referenced offline to an average of both mastoids. Epochs of 1000 ms after stimulus onset were computed relative to an additional 200 ms pre-stimulus baseline. An automatic rejection of trials containing amplitude shifts of more than 30 μV for the two eye channels and 40 μV for CZ and PZ within a sliding window of 200 ms was applied. Additionally, all trials were visually inspected for artifacts. Trials were averaged for each condition and participant, and for each condition across participants (grand average). Participants with less than 15 artifact-free trials left in one of the conditions were excluded from the analysis.

EEG data analysis. After visual inspection of the grand averages and a time-line analysis with 50 ms time windows, a time window between 190-250 ms was chosen for the quantification of the conflict N200 in the visual experiments. For the auditory experiments a conflict negativity was elicited in a later time window (420-550 ms). Even though the latency of the components in the auditory and visual experiments was different, they are both referred to as conflict N200. The adequacy of this denomination is discussed in detail in Chapters 2, 8, and 9. Channels were grouped into four regions of interest (ROI) with eleven electrodes each (see Figure 6.1). Repeated-measures analyses of variance (ANOVAs) including the within-factors conflict (congruent, incongruent), emotion (emotional [either negative or positive], neutral), region (anterior, posterior) as well as hemisphere (left, right) were computed. Significant main effects and interactions were followed-up by simple effects analyses. Only interactions that yielded significant effects in follow-up analyses are reported. As the conflict N200 has mainly been reported over anterior electrode sites (Veen & Carter, 2002b), an analysis was always done for the anterior region. As a measure of effect size, ω^2 (Kirk, 1995) is reported, when the size of effects is compared[1]. Individual scores in the scales effortful control, depression, anxiety, and stress (see Section 6.3) were correlated with the conflict effects. In line with a widely accepted nomenclature (see, e.g., Fan et al., 2002), the difference between incongruent and congruent trials is referred to as *conflict* effect, this applies to any type of data, be it behavioral or other. The congruent trials are always subtracted from the incongruent ones, i.e., conflict = incongruent - congruent. Also, the relation of the questionnaire scores (see Section 6.3) to the interaction effect of emotion and conflict were investigated. For this purpose, the difference between the conflict effects in emotional and neutral trials was computed. The interaction of conflict and emotion is henceforth referred to as *emotion conflict* and computed by subtracting the conflict effect in neutral trials from the conflict effect in emotional trials, i.e., emotion conflict = negative/positive conflict - neutral conflict. This difference is correlated with the questionnaire scores.

[1]The following levels of effect sizes were defined: ω^2 = .010 is a small effect; ω^2 = .059 is a medium-sized effect; ω^2 = .138 is a large effect (Kotrlik & Williams, 2003).

Software. Stimulus presentation and recording of the behavioral data was done with ERTS (experimental run time system, Berisoft Cooperation, Frankfurt, Germany) in the visual experiments and with Presentation 12.0 (Neurobehavioral Systems, Albany, CA, USA) in the auditory experiments. EEG data was recorded with brain vision professional recorder software (Brain Products GmbH, Gilching, Germany) in Experiments 1, 2, and 5. In Experiment 4, xrefa recording software (Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany) was used. EEG data analysis was done with the software package EEP 3.2 (ERP Evaluation Package EEP) developed at the Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany. Preparation of Figures was also done with EEP. For statistical analyses of behavioral, questionnaire, and EEG data, the software packages SAS 8.2 (SAS Institute Inc., Cary, NC, USA) and SPSS 15.0 (SPSS Inc.,Chicago, IL, USA) were used.

6.2 fMRI experiments

fMRI recording. MRI data were collected at 3.0 T using a Bruker 30/100 Medspec system (Bruker Medizintechnik GmbH, Ettlingen, Germany). A standard bird cage head coil was used. The experiments consisted of two separate, but consecutive sessions. In the first session, high resolution whole-head 3D MDEFT brain scans (128 sagittal slices, 1.5 mm thickness, FOV 25:0 - 25:0 - 19:2 cm, data matrix of 256 - 256 voxels) were acquired to improve localization (Ugurbil et al., 1993). The second session started with the collection of scout spin echo sagittal scans to define the anterior and posterior commissures on a midline sagittal section. For each participant, structural and functional (echo-planar) images (EPI) were obtained from 22 axial slices parallel to the plane intersecting the anterior and posterior commissures (AC-PC plane). The most inferior slice was positioned below the AC-PC plane and the remaining slices were extended dorsally. The whole range of slices covered almost the entire brain. For functional imaging, a gradient-echo EPI sequence was used with a TE of 30 ms, a flip angle of 90°, a TR of 2000 ms, and an acquisition bandwidth of 100 kHz. The matrix acquired was 64 x 64 with a FOV of 19.2 cm, resulting in an in-plane resolution of 3 x 3 mm. The slice thickness was 4 mm with an interslice gap of 1 mm. To align the functional EPI images to 3D-MDEFT images, conventional T1 weighted, MDEFT, and T1 weighted EPI images were obtained in-plane with the T2* echo-planar images as reference.

fMRI data processing. The data processing was performed using the software package LIPSIA (Leipzig Image Processing and Statistical Inference Algorithms; Lohmann et al., 2001). This software package contains tools for preprocessing, co-registration, statistical evaluation, and visualization of fMRI data. Functional data were corrected for motion using a matching metric based on linear correlation. To correct for the temporal offset between the slices acquired in one scan, a cubic-spline-interpolation was applied. A temporal highpass filter with a cutoff frequency of 1/104 Hz was used for baseline correction of the signal, as well as a spatial gaussian filter with 4.24 mm FWHM. To align the functional dataslices with a 3D stereotactic coordinate reference system, a rigid linear registration with six degrees of freedom (3 rotational, 3 translational) was performed. The rotational and translational parameters were acquired on the basis of the MDEFT (Ugurbil et al., 1993; Norris, 2000) and EPI-T1 slices to achieve an optimal match between these slices and the individual 3D reference data set. This 3D reference data set was acquired for each participant during a previous scanning session. The MDEFT volume data set with 160 slices and 1 mm slice thickness was standardized to the Talairach stereotactic space (Talairach & Tournoux, 1988). The rotational and translational parameters were subsequently transformed by linear scaling to a standard size. The resulting parameters were then used to transform the functional slices using trilinear interpolation so that the resulting functional slices were aligned with the stereotactic coordinate system. This linear normalization process was improved by a subsequent processing step that performed an additional nonlinear normalization.

fMRI data analysis. The statistical evaluation was based on a least-squares estimation using the general linear model for serially autocorrelated observations (Friston, 1994; Friston, Holmes, Poline, et al., 1995; Friston, Holmes, Worsley, et al., 1995; Worsley & Friston, 1995). The design matrix was generated with a synthetic hemodynamic response function (Josephs, Turner, & Friston, 1997; Friston et al., 1998) and its first derivative. The model equation, including the observation data, the design matrix and the error term, was convolved with a Gaussian kernel of dispersion of 4 s FWHM to deal with the temporal autocorrelation (Worsley & Friston, 1995). In the following, contrast-images, i.e., estimates of the raw-score differences between specified conditions, were generated for each participant. As noted before, each individual functional dataset was aligned with the standard stereotactic reference space, so that a group analysis based on the contrast-images could be performed. The contrast between the different conditions was calculated using the t-statistic. Subsequently, t-values were transformed into Z-scores.

A multiple comparisons correction was done using Monte-Carlo simulations. All reported activations survived a threshold corresponding to $p < 0.05$. As there were strong hypotheses about activation in the amygdala for negative compared to neutral trials, in a first step of analysis a less stringent threshold was used to investigate amygdala activations (a critical Z-score of greater than 2.33 ($p < 0.01$) and a volume threshold of greater than 108 mm^3 (4 measured voxels), see, e.g., Nomura et al. (2004). In a second step regions of interest (ROI) consisting of 8 adjacent voxels were defined around the peak activations in the left and right amygdala and the average BOLD signal change was entered into an ANOVA testing for the effects of emotion and conflict. A time-line statistic was also conducted for regions in the anterior cingulate cortex averaging BOLD signal change around the peak response for all voxels in the clusters.

Software. Stimulus presentation and recording of the behavioral data was done with ERTS (experimental run time system, Berisoft Cooperation, Frankfurt, Germany) in the visual experiments and with Presentation 12.0 (Neurobehavioral Systems, Albany, CA, USA) in the auditory experiments. Imaging data was analyzed with LIPSIA (Leipzig Image Processing and Statistical Inference Algorithms; Lohmann et al., 2001). For statistical analyses of behavioral and questionnaire data, the software packages SAS 8.2 (SAS Institute Inc., Cary, NC, USA) and SPSS 15.0 (SPSS Inc.,Chicago, IL, USA) were used.

6.3 Questionnaires

6.3.1 Adult temperament questionnaire

The Adult Temperament Questionnaire (ATQ) was developed by Rothbart and colleagues (Rothbart et al., 2000) and is based on the Physiological Reactions Questionnaire developed by Derryberry and Rothbart (1988). It aims at measuring the following four general constructs: effortful control, negative affect, extraversion/surgency, and orienting sensitivity. In the questionnaire the general constructs are referred to as factor scales. As explained in Chapter 4, for the current experiments effortful control was of special interest, the other factor scales were not used. Three sub-constructs, which the authors refer to as scales, constitute effortful control: inhibitory control, activation control, and attentional control. In the ATQ long form, which was used in the experiments, the factor scale effortful control included 35 items. In addition to including general constructs and sub-constructs, the long form also sub-divides the sub-construct attentional control into homogeneous item clusters. All items are displayed in Appendix A.1 in Table A.2. There were seven response options for each item ranging from “extremely untrue” (trifft gar nicht zu) to “extremely true” (trifft absolut zu) and an option “not applicable” (nicht anwendbar). See Appendix A.1 Table A.1 for all response options. The reliability of the scales is acceptable for temperament questionnaires (see Table 6.2; reliabilities were taken from the ATQ manual obtained through the authors’ homepage[2]).

Scales	α
Effortful Control	.75
Inhibitory Control	.65
Activation Control	.84
Attentional Control	.88

Table 6.2: Reliability of effortful control and its scales. α was computed based on a sample of 258 undergraduate students.

As, to date, no German translation of the ATQ exists, the items constituting the effortful control factor scale were translated by the author and checked by a bilingual member of the group[3]. The validation of the reliability of the scales in German was beyond the scope of the current study. However, the target population (undergraduate students) was the same as in the English validation studies. This should add to comparability. Missing values, i.e., non-responses etc., were treated according to the suggestions by Rothbart and colleagues. There is typically a minimal number of 1) non-responses, 2) more than one response for the same item, 3) and selection of the “not applicable“ response option (i.e., all three of these cases constitute missing values). The mean item response from the whole sample was inserted to replace these missing values.

6.3.2 Depression anxiety stress scales

To assess depression and anxiety, the Depression Anxiety Stress Scales (DASS) were applied (Lovibond & Lovibond, 1995). The development of the questionnaire originally aimed at reliably differentiating depression and anxiety. During the development a third scale, named

[2]http://www.bowdoin.edu/ sputnam/rothbart-temperament-questionnaires/
[3]Special thanks to Susan Bobb for help with the translation.

stress, evolved and was included in the questionnaire. Each scale consists of 14 items that are listed in Appendix A.2 in Table A.4. In the instruction participants are asked to evaluate whether an item applied to them during the last week. There were four response options ranging from ”did not apply to me at all” (traf gar nicht auf mich zu) to ”applied to me very much, or most of the time“ (traf sehr stark auf mich zu, oder die meiste Zeit). For the exact instruction and all response options see Appendix A.2. Reliability of the three scales is considered adequate (see Table 6.3).

	α	
Scales	Nonclinical	Clinical
Depression	.91	.96
Anxiety	.84	.89
Stress	.90	.93

Table 6.3: Reliability of the DASS. α was computed based on a sample of 717 nonclinical participants (Lovibond & Lovibond, 1995) and 437 clinical participants (Brown, Chorpita, Korotitsch, & Barlow, 1997).

For the present study a German translation of the DASS provided by the University of New South Wales, Sidney, Australia, was used[4]. To our knowledge, there are no published norms of the German version. In order to be consistent, as for the ATQ, the mean item response from the whole sample was inserted to replace missing values.

[4]http://www2.psy.unsw.edu.au/groups/dass/

Chapter 7

Visual experiments

The experiments reported here aimed at testing the effect of emotion on attentional control. Previous research targeting this question yielded partly inconsistent results, the question, therefore, remains open (see Section 3.4). A novel design, overcoming some of the caveats of earlier work, was used in which emotional words were presented in a flanker task.

The chapter starts with a general description of the experimental design that was applied in all visual experiments (Section 7.1). Some specifics regarding the individual experiments are given. The next section includes a description of how the stimuli for the visual experiments were selected based on several ratings of a large sample of words (Section 7.2). The rating procedures are described in detail to exemplify the great care that was taken in preparation of the stimulus material. Then, a behavioral control experiment is reported (Section 7.3). It mainly aimed at studying the effects of the selected positive and negative emotional words on alerting and orienting of attention, thereby testing whether the word stimuli chosen were suited for investigating attentional effects of emotion before using them in a novel design. In the following three sections the particular methodological parameters and results of two EEG and one fMRI study examining the neural basis of an emotional modulation of executive attention are delineated. Section 7.4 describes the ERP effects of negative words, whereas Section 7.6 contains an fMRI experiment on the neuroanatomical basis of these effects. The influence of positive emotional words is subject of an EEG experiment described in Section 7.5. The results of each experiment are briefly discussed in the corresponding section with a focus on the main question that the experiment aimed at. A more elaborate discussion and critical evaluation of the results, including a cross-experimental view is attempted in Chapter 9.

7.1 Visual paradigm

In the past, two groups aimed at studying the influence of emotional stimuli on executive control of attention (see Section 3.4). Kuhl et al. (Kuhl & Kazén, 1999; Kazén & Kuhl, 2005) presented emotional words shortly before two Stroop trials. They observed a reduction in Stroop interference after positive emotional words, but only on the first of the two Stroop stimuli, and only when a second Stroop stimulus was presented. There was a numerical effect for negative words that did not reach significance. Instead of words, Dennis et al. (Dennis et al., 2007; Dennis & Chen, 2007a, 2007b) presented emotional faces preceding an arrow flanker task. The effects of the emotional faces on the flanker task performance were very complex. Fearful faces in interaction with the anxiety level of the participants reduced flanker interference in some of the experiments, but not all.

Several questions arise, all entwining around the fragility and inconsistency of the effects. Why are the effects of words only present on the first of two successive Stroop stimuli? Why only for positive words? Especially as fearful faces, under certain conditions, seem to enhance executive attention too? One answer may lie in the specific design that had been applied. The effect of emotional stimuli on, e.g., orienting of attention is studied through presentation of the emotional stimulus as the orienting cue (e.g., Pourtois, Thut, et al., 2005). However, the designs described above present the emotional stimuli as unrelated preceding stimuli, that are detached from the behaviorally relevant target stimulus. If emotion triggers and guides attentional control (Norman & Shallice, 1986) through rapid evaluation of stimuli regarding current goals (Scherer, 1994), than it should only facilitate reaction to that stimulus. Therefore, a different design was developed in which the target stimuli themselves were emotional. This design is described below. Also, some technical details for the experiments are given.

Participants performed a color flanker task (see Figure 7.1). The goal was to determine the print color of a target word presented at fixation (see Appendix B for the exact instructions). Two identical flanker words in either the same or a different color were presented above and below the target word. This yielded congruent (target and flanker words in the same color) and incongruent (target and flankers in different colors) stimulus situations. The words were emotionally neutral, negative, or positive. This allowed studying attentional control in reactions to emotional and neutral stimuli.

All stimuli were presented in upper case; the target array extended to maximally 2.3° of visual angle horizontally and 1.2° vertically from fixation. The sequence of events in a trial started with a fixation cross followed by the presentation of the word stimuli. At offset of the words a fixation cross reappeared. One trial lasted 6000 ms. Corresponding to the literature on flanker tasks (e.g., Fan et al., 2005) the stimuli were presented until the participants made a response, but for maximally 2000 ms. Onset of the stimuli in the trial was jittered between 0 and 2000 ms to avoid temporal orienting and, in the fMRI experiment, to allow for measurements at numerous time points along the BOLD signal curve. Each word was presented twice, once as an incongruent, and once as a congruent stimulus. The number of trials is therefore twice the number of words in the sample (see Section 7.2 for the word samples used). In the fMRI experiment 20 null events were added (i.e., trials without any stimulation).

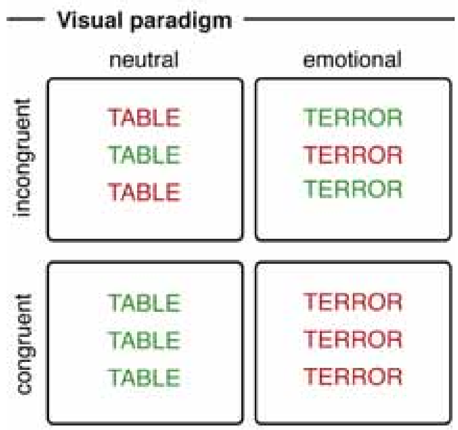

Figure 7.1: Visual paradigm: Variant of the flanker task with emotional and neutral items. Participants determine the print color of the central words, neglecting the color of the flanker words above and below.

For the EEG experiments, participants were seated in a comfortable chair in a sound-attenuated electrically shielded room. The computer monitor was positioned 80 cm in front of the participant as measured from the eyes. After instruction and application of the EEG cap, participants completed a practice block of 16 trials. The practice items were not part of the experimental blocks. For the fMRI experiment the training was done outside of the scanner. Stimuli were projected onto a screen within the imaging chamber viewable by a mirror approximately 5 cm from the subjects eyes. Mapping of response options to left and right response keys was counterbalanced across participants.

7.2 Visual stimuli construction and rating study 1

For the purpose of testing an effect of emotion on attentional control, emotional stimuli were required. Using emotional verbal material offers some advantages over the more often applied emotional faces and pictures (see Chapter 3). These advantages mainly relate to control issues. For emotional images and facial expressions there is no information on the frequency of occurrence in everyday life. While one could imagine that the relative time people are exposed to happy, sad, or neutral facial expressions varies, this point is even more relevant for research on emotional pictures. Often images of opposite-sex nudes and mutilations are used in emotional categories, whereas things like shopping malls, laundry machines, or office scenes fill neutral categories. This may confound emotion with frequency of occurrence (for an attempt to overcome this problem see Libkuman et al., 2007). For words there are estimates of frequency of usage in everyday situations that can be utilized to avoid such a confound. The point is relevant, as frequency largely affects stimulus processing (see, e.g., Kutas & Federmeier, 2000). Also, emotional images may vary in whether humans are depicted, if human eyes are present, if there is interaction between humans or not, etc. These factors do influence the processing of stimuli (e.g., Morris, deBonis, & Dolan, 2002). Additionally, it is difficult to control several physical attributes of the stimuli, such as brightness, colors, or complexity. All these factors can be very well controlled when visually presenting words. As recent reports of comparable electrophysiological and neural effects of emotion in words and other types of stimuli are accumulating (see Section 3.3), these stimuli were chosen for the experiments in the present thesis.

Several parameters were controlled including the length of the words as measured in number of letters and number of syllables. This should ensure control of physical features of the stimuli, as they were also all presented in capital letters, all in the same font. Frequency of usage was controlled using a database provided by the University of Leipzig. Concreteness affects word processing, and even interacts with emotion (Kanske & Kotz, 2007). Participants in a rating experiment therefore rated a large sample of words in concreteness, and emotional valence and arousal which were the main factors to be manipulated. From this large sample, subsamples of negative, neutral, and positive words were selected that satisfied the strict control criteria.

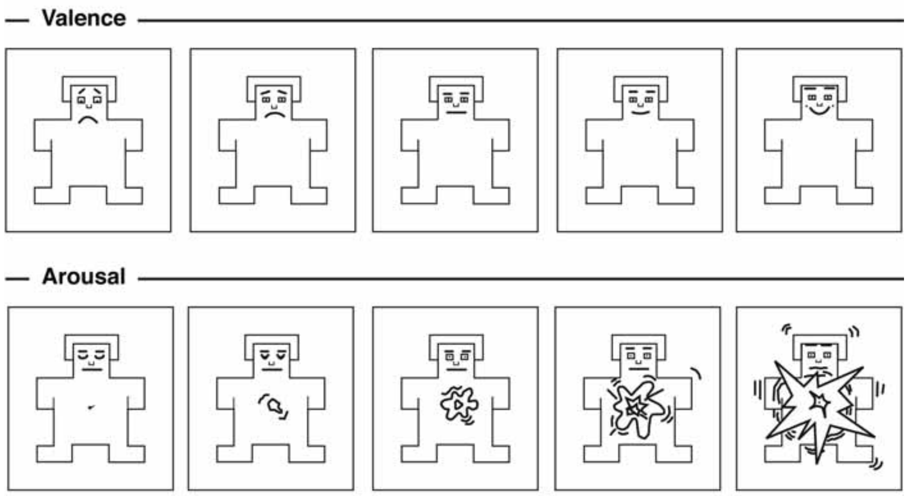

Figure 7.2: Self Assessment Manikins for the measurement of valence and arousal (Hodes, Cook, & Lang, 1985).

7.2.1 Methods

Participants. Thirty-two participants (16 female) volunteered in the rating study. All were native speakers of German. As handedness does not influence the behavioral performance in emotion or concreteness rating tasks, handedness was not controlled for (Rodway, Wright, & Hardie, 2003). The resulting mean laterality quotient according to the Edinburgh Handedness Inventory (Oldfield, 1971) was 72.3 (SD 47.8). All participants reported normal or corrected-to-normal vision.

Material. One-thousand German nouns were selected from Duden (Dudenredaktion, 2000). Only one- and two-syllable words were included to minimize variance in the visual angle of the presented stimuli. For the same reason, number of letters only varied between 3 and 8. Frequency of usage was taken from the Wortschatz Lexikon of the University of Leipzig (see Quasthoff, 1998; Biemann, Bordag, Heyer, Quasthoff, & Wolf, 2004) and the lexicon's homepage[1] and ranged from 8 to 18 (Mean 12.6, SD 2.4). The frequency of a word in the Wortschatz Lexikon is determined in comparison to the frequency of the word "der": If n(Hund) is the absolute frequency of the word "Hund" and n(der) is the absolute frequency of the word "der", then: frequency(Hund) = $\log_2$(n(der)/n(Hund)). In other words, if the frequency of

[1] http://wortschatz.uni-leipzig.de/

"Hund" is 10 it means that "der" is 2^{10} times more frequent than "Hund". This procedure yields a frequency measure that approaches normal distribution and is therefore better suited for subsequent statistical analysis. Frequency of usage needs to be controlled as high- and low-frequency words are processed differently (for examples see Bruder, 1978; Proverbio et al., 2008). Also, emotion has been shown to interact with word frequency (in EEG and fMRI, Nakic et al., 2006; Scott et al., 2008)

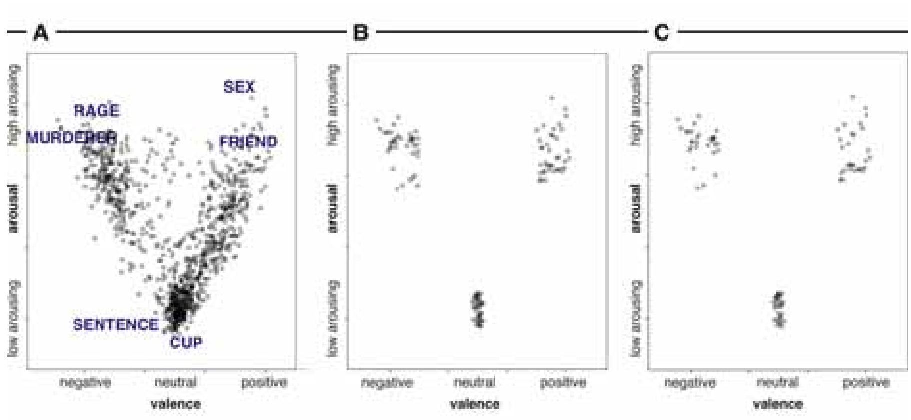

Figure 7.3: Scatter plots for valence and arousal ratings of 1000 rated words (A), the 120 words (B), and the 90 words selection (C).

Procedure. Participants came to the lab for two sessions in which they rated the words for valence (negative - neutral - positive), arousal (high arousing - low arousing), and concreteness (concrete - abstract). The order of the tasks was counter-balanced, two ratings were always completed in the first session, one rating in the second session. Rating was done on 9-point scales. For valence and arousal ratings the Self Assessment Manikins (Hodes et al., 1985; Bradley & Lang, 1994) were used (see Figure 7.2). For the concreteness rating the endpoints of the scale (concrete-abstract) were presented as words (see Appendix B for the precise instructions). The assignment of the scale endpoints to the left and right was counterbalanced across participants. Words were presented in upper case on the center of the screen for maximally 5000 ms. They extended to maximally 2.3° of visual angle horizontally and 0.4° vertically from fixation. Presentation of a word ended as soon as the participant pressed a button.

7.2.2 Results

The valence and arousal ratings of the 1000 words resulted in a typical U-shaped function. Words high in negative and positive valence were rated more arousing than neutral words (see Figure 7.3A). From these words two samples of different size were selected to enable a short and a long version of the main experiments. The long version was used in the behavioral control study (Section 7.3) and in the auditory experiments (see Chapter 8), the short version was applied in Experiments 1 through 3 (Sections 7.4, 7.5, 7.6). The first sample (120 words) consisted of 40 negative, 40 neutral, and 40 positive words (see Figure 7.3B) and the second (90 words) was a subsample of these 120 words with 30 negative, 30 neutral, and 30 positive words (see Figure 7.3C). These words were chosen to satisfy several criteria (see Table 7.1 for the descriptives of the samples in valence, arousal, concreteness, frequency of usage and word length in number of letters and number of syllables; Tables 7.2, 7.3 display the statistics). In each sample the groups differed significantly in valence (negative < neutral < positive) and arousal (negative = positive > neutral). However, there were no differences in concreteness, word frequency, and number of letters and syllables. All selected stimuli are displayed in Table C.1 in Appendix C.

	Valence	Arousal	Concreteness	Frequency	Letters	Syllables
120 words selection						
negative	2.4 (0.4)	6.8 (0.5)	6.3 (1.5)	11.0 (1.9)	5.5 (1.1)	1.7 (0.5)
neutral	5.0 (0.1)	2.3 (0.3)	6.0 (1.3)	11.3 (1.9)	5.9 (1.1)	1.8 (0.4)
positive	7.5 (0.3)	6.6 (0.6)	6.2 (1.7)	10.7 (2.0)	5.8 (1.3)	1.7 (0.5)
90 words selection						
negative	2.4 (0.4)	6.9 (0.5)	6.3 (1.3)	11.0 (2.1)	5.5 (1.1)	1.7 (0.5)
neutral	5.0 (0.1)	2.3 (0.3)	6.0 (1.3)	11.1 (1.9)	5.9 (1.0)	1.8 (0.4)
positive	7.6 (0.3)	6.7 (0.6)	6.3 (1.8)	10.7 (2.2)	5.7 (1.3)	1.7 (0.4)

Table 7.1: Descriptives for the selected words. Means and standard deviations (in parentheses) are given. The upper panel shows the values for the 120 words selection whereas those for the 90 words selection are displayed in the lower panel.

7.2.3 Discussion

The rating study provided valence, arousal, and concreteness norms for a large sample of words. Based on these norms, as well as frequency of usage and word length, samples of 90 and 120 words were created to be used in the experiments. These samples consisted of three groups of

Effect	*df*	*F value*	*p-value*
120 words selection			
valence	2,117	2950.9	<.001
arousal	2,117	1128.9	<.001
concreteness	2,117	.3	>.70
word frequency	2,117	.9	>.40
letters	2,117	1.1	>.30
syllables	2,117	.8	>.40
90 words selection			
valence	2,87	2129.6	<.001
arousal	2,87	813.2	<.001
concreteness	2,87	.3	>.70
word frequency	2,87	.3	>.70
letters	2,87	.8	>.40
syllables	2,87	1.1	>.30

Table 7.2: Statistics for the selected words. The main effects of emotional word group (negative, neutral, positive) in valence, arousal, and concreteness ratings, as well as frequency, number of letters and number of syllables are displayed. The upper panel shows the 120 words selection, and the lower panel the 90 words selection.

words; negative, positive, and neutral. Negative and positive words were also more arousing than neutral words. There were no differences in concreteness, frequency of usage, or word length (neither number of letters, nor number of syllables).

The U-shaped relation of valence and arousal that was found in the present word sample has also been reported for emotional pictures (Lang, Bradley, & Cuthbert, 1995; Ito, Cacioppo, & Lang, 1998) and for a sample of English words (Bradley & Lang, 1999). It is therefore assumed that arousal and valence were validly measured in the present rating. Often, negative stimuli are found to be slightly more arousing. However, due to the large amount of words that were rated here, it was possible to create samples of negative and positive stimuli that did not differ in arousal. Any difference that might be present in the effects of negative and positive words on attention can therefore clearly be attributed to valence. The participants who rated the words were relatively similar to the participants in the main experiments regarding age, profession (mostly students), German mother tongue, and handedness (even though handedness was not explicitly controlled in the rating study, the resulting LQ indicated mainly right-handedness). Therefore, the affective ratings of the words should be generalizable to participants in the main experiments. Comparing the ratings and lexical characteristica of the two samples of words (90 and 120 words) it is apparent that they are almost identical (in means and standard deviations).

	p-value	
Effect	Valence	Arousal
120 words selection		
negative vs. neutral	<.001	<.001
positive vs. neutral	<.001	<.001
negative vs. positive	<.001	>.20
90 words selection		
negative vs. neutral	<.001	<.001
positive vs. neutral	<.001	<.001
negative vs. positive	<.001	>.20

Table 7.3: Scheffé's multiple comparisons t test for the selected words. Contrasts were computed for the significant main effects in valence and arousal to test whether negative, positive, and neutral words differed. The 120 words selection is shown in the upper panel, the 90 words selection in the lower panel.

This is not surprising as the 90 words are just a subsample of the 120 words. However, it is important as no difference in effects can be expected when applying either one of these two samples.

In conclusion, a highly controlled list of emotional and neutral words was created that could be applied in experiments that assess the impact of emotional word stimuli on attention.

7.3 Behavioral control study: Attention effects of emotional words

The rating study yielded groups of words that were significantly differentiable in emotional valence and arousal. The behavioral control experiment was conducted to further validate the created sample of emotional words, before using them in a novel design testing the effects of emotion on control of attention. For this purpose a paradigm was used that is sensitive to attention effects of emotional stimuli. If the selected words replicate the known attention effects of other emotional stimuli in this paradigm, they should be well suited for studying emotion effects in a new design.

As described in Section 3.3, when using emotional and neutral cues in the orienting paradigm, participants react faster to target stimuli at locations cued by emotional stimuli. Also, when the cue was invalid and the target appeared at a different location than the cue predicted, RTs increased for emotional cues. Stormark et al. (1995) concluded that emotional stimuli orient attention faster and capture attention longer than neutral stimuli. This effect has mainly been shown for negative stimuli. A recent exception is a study using positively valenced infant faces that also oriented attention faster (Brosch, Sander, Pourtois, & Scherer, 2008). However, there is no study with positive emotional words yet. The control study also included a cue condition that was not informative with regard to the location of the target. This condition allowed testing whether emotional words were also more alerting than neutral words (this design was adapted from Fan et al., 2002). Lastly, the flanker task with emotional words described in Section 7.1 was also applied to pilot an effect of emotion on attentional control in the same participants who did the orienting and alerting task.

To summarize, the major questions were:

1. Can the effects of emotional stimuli on orienting of attention be replicated with the present sample of words? This would make them well-suited for application in a novel design testing emotion effects on executive attention.

2. Are these effects also present for positive emotional words?

3. Do emotional words influence alerting too? This would yield further evidence for the salience of the selected material.

4. Can effects of emotional words on executive control of attention be found in the same subjects in which orienting and/or alerting effects are present?

7.3.1 Methods

Participants. Ten (5 female) participants were invited for the experiment. Mean age was 23.8 years (SD 1.6). All participants were native speakers of German, right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean laterality quotient of 95.2 (SD 5.4), and reported normal or corrected-to-normal vision. Data from one participant had to be excluded from the analysis of the flanker task as the recording could not be completed.

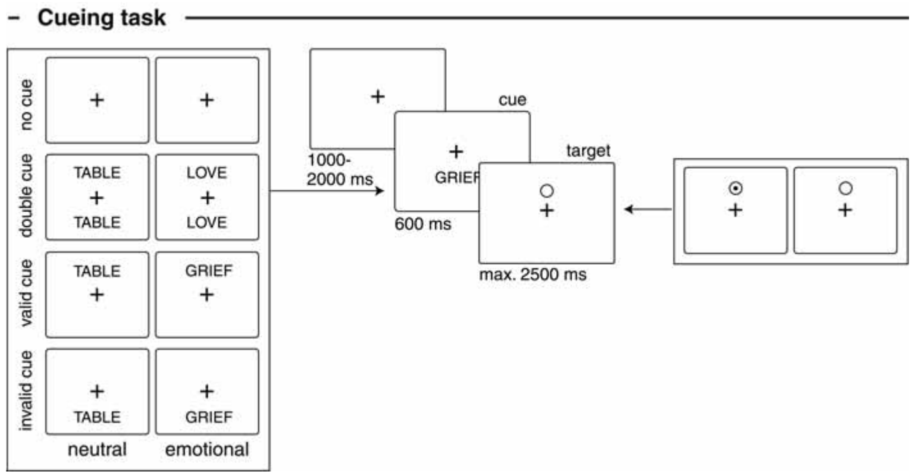

Figure 7.4: Cueing paradigm: Variant of the cueing task with emotional and neutral items. Participants decided whether a target circle included a dot or not. Words were presented as cues before the target appeared.

Task and materials. The two tasks were administered in separate sessions, which were at least one week apart. Order of the two tasks was counterbalanced. Participants performed the color flanker task described in Section 7.1 (see Figure 7.1). The words that were used were either negative, positive, or neutral (see Section 7.2). Additionally, a cueing task was administered (see Figure 7.4). Participants were to decide whether a target circle presented above or below fixation contained a dot, which it did in 50% of the cases. In some trials a cue was presented prior to the target. There were different cue categories:

- Double cues were presented above and below fixation. Thus, they were alerting, but not informative with regard to the location of the target.

- Valid cues were presented either above or below fixation, but always at the location of the following target. Thus, they were informative with regard to the location. Participants could orient attention to that location prior to target presentation.

- Invalid cues were also presented either above or below fixation, but always at the location where the following target did not appear. Thus, they were misleading in regard to the target location. At target presentation participants had to reorient attention from the spuriously cued location to the target location.

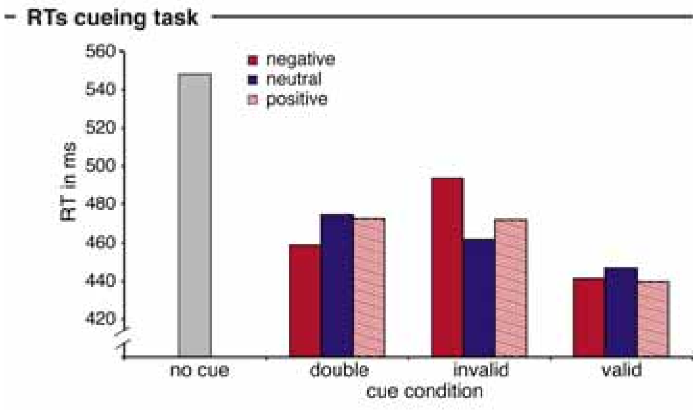

Figure 7.5: Reaction times in the cueing task. Participants responded faster when a cue was presented. The effect of emotional vs. neutral cues depended on the specific cue condition

Cues were always a single word that were either emotionally negative, positive, or neutral. All in all there were 880 trials, 40 trials with no cue, 120 (40 negative, 40 neutral, 40 positive) trials with a double cue and the same number of invalid cue trials. There were 600 (200 negative, 200 neutral, 200 positive) valid cue trials yielding a ratio of 1:5 for invalid:valid trials to keep a single cue informative enough for participants to orient attention to the cue location. Presentation time of the cues was 600 ms followed by the target, which was displayed until the participants response, but maximally for 2500 ms (analogous to Stormark et al., 1995). The next trial started after a random interval of 1000 to 2000 ms. The cues were presented 1.6° above or below fixation and extended to maximally 2.3° horizontally. The computer monitor was positioned 80 cm in front of the participant as measured from the eyes.

Word Condition	No Cue	Double	Invalid	Valid
negative		458.6 (39.3)	493.5 (61.2)	441.1 (40.6)
neutral	548.0 (183.4)	474.7 (49.9)	461.7 (49.2)	446.5 (40.6)
positive		472.8 (47.5)	472.2 (53.3)	439.6 (44.9)

Table 7.4: Reaction times in the cueing task. Means and standard deviations (in parentheses) are given.

7.3.2 Results

Cueing task. 94.3% (SD 5.2) of all trials were responded to correctly (RT mean = 462.3 ms, SD 47,4). As there were no significant effects on accuracy, only the statistics for the RTs are reported. There was a significant effect of cue condition (see Figure 7.5 and Table 7.4; F(2,18) = 7.1, P < .05). A Geisser-Greenhouse correction (Geisser & Greenhouse, 1959) was applied to all repeated measures with more than one degree of freedom. Emotion did not affect RTs, but there was a significant interaction of emotion and cue condition (F(4,36) = 8.6, P < .01). Follow-up analyses revealed an interesting pattern of results. Negative emotional cues sped up responses in the double and valid cue condition compared to neutral cues (F(1,9) = 8.7, P < .05; F(1,9) = 8.1, P < .05, respectively), but slowed responses in the invalid cue condition (F(1,9) = 11.8, P < .01). Positive emotional stimuli had the same effect in the valid and invalid cue condition (F(1,9) = 7.7, P < .05; F(1,9) = 10.9, P < .01, respectively), but there was no significant effect in the double cue condition (F(1,9) = 0.5, P > .40).

Flanker task. 98.2% (SD 4.1) of all trials were responded to correctly (RT mean = 452.8 ms, SD 59.7). As there were no significant effects on accuracy, only the statistics for the RTs are reported. There was a significant conflict effect; RTs were shorter for congruent compared to incongruent trials (see Figure 7.6 and Table 7.5; F(1,8) = 19.3, P < .01). Emotion also had a significant effect on RTs (F(2,16) = 4.1, P < .05), as did the interaction of emotion and conflict (F(2,16) = 4.9, P < .01). The Geisser-Greenhouse correction (Geisser & Greenhouse, 1959) was applied to all repeated measures with more than one degree of freedom. Follow-up analyses revealed that the conflict effect was smaller for negative and positive compared to neutral trials (F(1,8) = 12.9, P < .01, ω^2 = 0.30; F(1,8) = 12.2, P < .01, ω^2 = 0.29; F(1,8) = 16.9, P < .01, ω^2 = 0.37; respectively). This effect was driven by differences between the emotional conditions for incongruent trials (F(2,16) = 8.6, P < .01), but not for congruent trials, where there were no RT differences between negative, positive, and neutral words (F(2,16) = 0.7, P > .50).

Word Condition	Congruent	Incongruent	Conflict
negative	433.4 (57.7)	452.7 (54.9)	19.2
neutral	438.4 (68.7)	481.3 (64.7)	42.9
positive	442.2 (65.1)	469.0 (56.4)	26.7

Table 7.5: Reaction times in the flanker task. Means and standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent conditions.

7.3.3 Discussion

Positive and negative emotional words decreased target detection time when they validly predicted the location of the subsequent target stimulus. In contrast, RTs were increased after an invalid emotional cue. This suggests that emotional words oriented attention. Negative emotional words also produced a larger alerting effect, positive words did not. Interestingly, emotional words also decreased the conflict effect by speeding up responses to incongruent stimuli.

The main purpose of the experiment was to test the effects of the selected emotional words in an established design. The orienting paradigm was chosen as it has been shown to be sensitive to emotional stimuli (e.g., Stormark et al., 1995). It is therefore encouraging that the present emotional word sample also sped orienting and captured attention which suggests that it may be used in a novel design studying the effect of emotion on control of attention. If there was no effect on attentional control, the possibility that this is due to problems that are specific to the emotional stimuli selected in this thesis, is reduced. Even though the effect of positive words was a bit smaller, especially in the invalid condition, it was still significant, replicating a recent study with positive infant faces (Brosch, Sander, et al., 2008). Alerting is also affected by emotion. Such an effect could be expected from previous research with animals and imaging showing alertness related activity to emotional stimuli (see Section 3.4). Also, the rated arousal dimension in the emotional words probably taps into that. However, even though negative and positive words did not differ in rated arousal, only negative words increased alerting. This may be an inherent feature of positive emotional stimuli (Ito & Cacioppo, 2005). It could, however, also be a technicality of the present experiment. Even though tiny, there is a numerical non-significant increase in alerting following a positive word. Replication in a larger sample, e.g., may provide clearer results. Also, the alerting effect could depend on the time interval between cue and target which may not have been optimal in the present experiment. Clearly, more research targeting alerting and emotion addressing these points is needed.

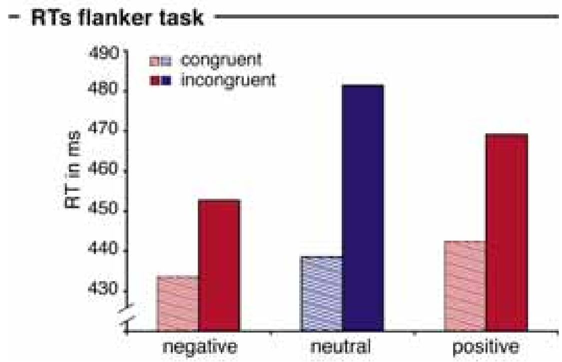

Figure 7.6: Reaction times in the flanker task. Participants responded faster in the congruent compared to the incongruent trials. Emotional words decreased the response times to incongruent stimuli.

This behavioral experiment also provided a first glimpse at the potential interaction of emotion and executive control of attention. The reduced RT conflict effect in emotional trials suggests that emotional stimuli not only increase alertness and orient attention, but also trigger executive control of attention (Norman & Shallice, 1986; Scherer, 1994). This effect was pursued in the following experiments to test whether it is reliable, how fast emotion may act upon executive attention, and what the neural basis of an interaction may be (see the following experiments for a more detailed discussion of the effect).

7.4 Experiment 1: Conflict N200 and negative emotion

The behavioral control study described in the previous section already hinted at the possibility that emotional stimuli presented as targets in a flanker task may influence control of attention. RT conflict was significantly reduced in emotional trials. The present experiment aimed at validating this result in a different and larger sample of participants. Most importantly, EEG was measured to gain insight into the time-course of an interaction of emotion and conflict processing. In a first step, only negative and neutral words were presented. The effects of positive emotional words were investigated in Experiment 2 (see Section 7.5).

Previous EEG experiments with flanker tasks produced a reliable effect around 200 ms poststimulus onset referred to as N200 (e.g., Gehring et al., 1992; Kopp et al., 1996). Incongruent stimuli elicit a larger N200 than congruent stimuli. The effect is largely independent of the exact stimulus used as it has been found for letters (Gehring et al., 1992; Bartholow et al., 2005) and arrows (Kopp et al., 1996; Ent, 2002). Modulation of the conflict N200 can be observed in development, aging, and psychopathology. The component emerges as the performance of children in the flanker task develops or when it is trained (Rueda, Rothbart, et al., 2005). It declines again in older participants with poorer performance (West, 2004) and is also reduced in ADHD patients with less efficient conflict processing abilities (Albrecht et al., 2008). These results suggest the interpretation of the N200 as indexing conflict processing. A behavioral facilitation in emotional trials should therefore be accompanied by an enlarged conflict N200. Early effects of emotional stimuli in the EEG are numerous, also for emotional words, evidence for very early emotion detection is accumulating (e.g., on the P1, Li et al., 2007; Scott et al., 2008; Hooff et al., 2008; Taake et al., 2008). These effects are indeed early enough to potentially allow emotion to exert an influence on conflict processing already as soon as 200 ms poststimulus.

Additionally, temperamental effortful control and the emotional state of the participants were assessed. As elaborated in Chapter 4, effortful control is associated with executive attention, but also with emotion regulation (Gerardi-Caulton, 2000; Rothbart et al., 2003; Kochanska et al., 2000). Depression and anxiety are related to altered processing of mainly negative emotional stimuli, suggesting deficiency in appropriate evaluation of significance of these emotional stimuli (e.g., Mercado et al., 2006; Siegle et al., 2007).

Experiment 1 therefore addressed several questions which are listed below, including hypotheses regarding the results:

1. Incongruent stimuli elicit conflict and are therefore reacted to slower than congruent stimuli. This should also be reflected in an enlarged N200 amplitude for incongruent trials.

2. If emotional stimuli exert influence over executive control of attention, the RT conflict effect should be modulated by emotional target words. Also, the conflict N200 may reflect this modulation, if early detection of emotion is influencing attentional control.

3. The influence of emotion on executive attention may depend on individuals temperamental effortful control and emotional state in subclinical depression and anxiety.

7.4.1 Methods

Participants. Twenty-six (14 female) participants were invited for the experiment. Mean age was 23.1 years (SD 1.7). All participants were native speakers of German, right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean laterality quotient of 94.7 (SD 7.6), and reported normal or corrected-to-normal vision.

Task and materials. Participants performed the color flanker task described in Section 7.1 (see Figure 7.1). The words that were used were of negative and neutral valence (see Section 7.2).

7.4.2 Results

Behavioral data. 97.4% (SD 3.5) of all trials were responded to correctly (RT mean = 516.7 ms, SD 62.0). As there were no significant effects on accuracy in any of the experiments, only the statistics for the RTs are reported. There was a significant conflict effect; RTs were shorter for congruent compared to incongruent trials (see Figure 7.7 and Table 7.6; $F(1,25) = 41.0$, $P < .0001$). Emotion did not have a significant effect on RTs, but the interaction of emotion and conflict was significant ($F(1,25) = 34.9$, $P < .0001$). Follow-up analyses revealed that the conflict effect was smaller for negative compared to neutral trials ($F(1,25) = 21.3$, $P < .0001$, $\omega^2 = 0.28$ vs. $F(1,25) = 58.0$, $P < .0001$, $\omega^2 = 0.52$). This effect was driven by reduced RTs to negative incongruent trials, when compared to neutral incongruent trials ($F(1,25) = 8.9$, $P < .01$,

ω^2 = 0.13). There was no difference between negative and neutral congruent trials (F(1,25) = 0.4, P > .50, ω^2 = 0.01).

Electrophysiological recordings. An N200 component starting around 190 ms with a larger amplitude for incongruent than congruent trials was observed. Figure 7.8 shows the difference waves of incongruent minus congruent trials for negative and neutral words. Repeated measures analyses on the mean amplitude between 190 and 250 ms yielded a significant interaction of conflict and region (F(1,25) = 6.6, P < .05) indicating a conflict effect over anterior, but not over posterior electrode sites (F(1,25) = 3.9, P < .05 vs. F(1,25) = 0.4, P > .50). There was also an interaction of emotion and conflict (F(1,25) = 6.49, P < .01). Follow-up analyses showed that the conflict effect was only significant for negative, not for neutral trials (F(1,25) = 5.3, P < .05 vs. F(1,25) = 0.6, P > .40). The interaction of emotion and conflict was significant over anterior and posterior electrodes (F(1,25) = 4.6, P < .05 vs. F(1,25) = 4.3, P < .05, respectively). However, follow-up analyses in the regions yielded a significant conflict effect only over anterior electrode-sites in negative trials, but not over posterior sites (F(1,25) = 7.6, P < .01 vs. F(1,25) = 0.5, P > .40, respectively). In neutral trials there was no conflict N200, neither over anterior, nor over posterior sites (F(1,25) = 0.1, P > .80 vs. F(1,25) = 3.1, P > .05, respectively).

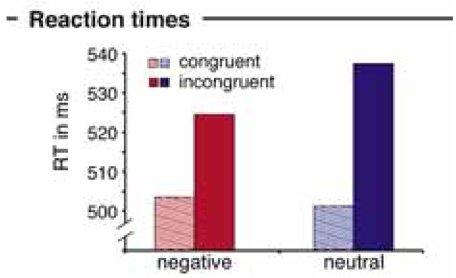

Figure 7.7: Reaction times in Experiment 1. Responses were slower in incongruent compared to congruent trials. The effect was modulated by emotion such that RTs in incongruent emotionally negative trials were reduced.

Correlational data. Effortful control negatively correlated with RT conflict, i.e., participants scoring high in effortful control showed smaller conflict effects (see Table 7.7). Effortful control was also negatively correlated to the interaction of emotion and conflict. Those participants with high effortful control showed an even smaller conflict effect in negative compared to neutral trials. Depression, anxiety, and stress were not related to RT conflict, but depression and anxiety showed a positive correlation with the interaction of RT conflict and emotion. Conflict resolution benefited less from emotional stimuli in individuals scoring high in depression and anxiety. Effortful control negatively correlated with the N200 conflict effect and with the N200 interaction effect. Participants with higher effortful control scores showed a larger N200 conflict response. This effect was larger in negative compared to neutral trials. High depression and anxiety scoring participants showed the opposite effects. In summary, effortful control was related to efficient conflict processing and larger benefits from emotion in RTs and the N200. In contrast, depression and anxiety exhibited less of a benefit in conflict processing from emotion.

Word Condition	Congruent	Incongruent	Conflict
negative	503.5 (58.5)	524.5 (60.9)	21.0
neutral	501.3 (65.0)	537.5 (65.1)	36.2

Table 7.6: Reaction times in Experiment 1. Means and standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent conditions.

7.4.3 Discussion

The present experiment tested the efficiency of attentional control in reaction to negative emotional and neutral stimuli. A RT conflict effect was present as participants responded faster to congruent compared to incongruent stimuli. In the ERP, this was reflected in an enlarged N200 for incongruent trials. The conflict effect was reduced by negative emotional stimuli which also enhanced the conflict N200. Effortful control, depression, and anxiety were associated with these effects.

As in the behavioral control study, the color flanker task proved to be an appropriate tool to study conflict processing. Previous studies mainly used arrow or letter flanker stimuli, showing that RT conflict and the elicitation of a conflict N200 in the ERP are independent of the exact stimuli used, as long as congruent and incongruent stimulus situations are created (Gehring et al., 1992; Kopp et al., 1996; Ent, 2002; Bartholow et al., 2005). The present experiment adds to this evidence as a conflict effect was found in RTs and the N200 in a color flanker task. This first step was vital as the main question of the experiment was whether the conflict main effect would be modulated by negative emotional stimuli.

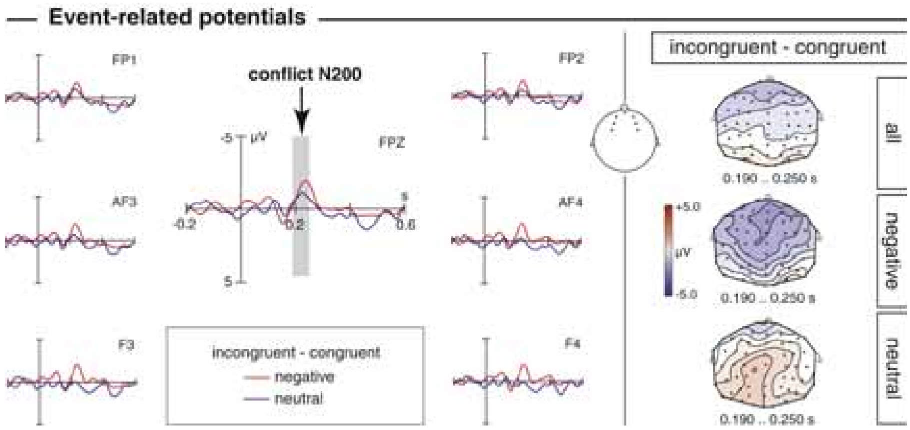

Figure 7.8: Event-related potentials in Experiment 1: Difference waves and difference maps for incongruent - congruent trials in the N200 time-window.

The reduced RT conflict effect in negative emotional stimuli suggests that executive control of attention is influenced by negative emotion. Norman and Shallice (1986) argued that control of attention may be triggered by certain situations including committed errors, novelty, or danger. This suggestion has been interpreted such that "more controlled processing takes place, when subjects are threatened" (p. 81, Seifert et al., 2006). In the present experiment, threat was not directly involved, and responses were not associated with negative consequences. Nevertheless, negative emotional words may have acted as signals of relevance, that require especially efficient control of attention in reactions and, thus, reduced RTs in incongruent stimulus situations.

As Scherer (1994) suggested, it may be that the emotional, as such relevance signaling, character of a stimulus guides attentional and consequently behavioral control. He did so on the ground that emotion helps to deal with the dilemmata of controlling action in an organism whose behavior is not solely based on rigid reflex-like stimulus-response mappings, i.e., in situations that might involve conflict. Emotion provides very fast evaluation of stimuli regarding current goals, which is the basis of response selection. Emotion also associates selected responses with motivational force, enabling fast and appropriate responses. These mechanisms could support conflict resolution, which seems to be the case in the present experiment where reactions to incongruent stimuli were faster when the stimuli were emotional.

This interpretation suggests that accuracy of performance should also reveal an interaction of emotion and conflict. The lack of such an effect in the error rates may be due to the simplicity

	RT		Anterior N200	
	Conflict	Emotion Conflict	Conflict	Emotion Conflict
effortful control	-.49*	-.39*	-.40*	-.43*
depression	-.04	.57**	-.04	.66**
anxiety	.12	.62**	-.03	.48*
stress	.11	.32	.01	-.15

Table 7.7: Correlations in Experiment 1: Pearson correlation coefficients of effortful control, depression, anxiety, and stress with RT and anterior ERP effects. As described in Chapter 6, conflict refers to the conflict main effect (incongruent - congruent), and emotion conflict to the interaction of emotion and conflict (conflict in negative trials - conflict in neutral trials). *<.05; **<.01

of the task. Over 97% of all trials were correct. This high accuracy seems to make it impossible to find effects of the experimental manipulations.

The behavioral facilitation of conflict processing in emotional stimuli is mirrored by an amplitude increase in the conflict N200. Such an N200 increase in combination with a RT decrease may seem counterintuitive at first glance, but it is in line with previous work on the N200 in certain populations. Participants with enhanced behavioral performance in conflict tasks often show an enlarged N200 potential (see Section 2.4, e.g., Albrecht et al., 2008). This evidence suggests the interpretation of the N200 as an index of conflict processing, not "just" conflict detection. Better behavioral performance should require stronger engagement of this process (or these processes) and result in an amplitude increase. This relation seems analogous to what has been reported for other phenomena, e.g., concreteness processing in words or attention in visual processing. Reactions to concrete words are faster than to abstract words, and accompanied by an enlarged N400 component. The common interpretation of this effect is that concrete words activate more semantic associations resulting in facilitated recognition (Kounios & Holcomb, 1994; West & Holcomb, 2000; Kanske & Kotz, 2007). For attended visual stimuli, an amplification of early potentials has been observed and interpreted as a mechanism of gain control over information flow in extrastriate visual areas (for a review see Hillyard & Anllo-Vento, 1998). In conclusion, the enlarged N200 potentially reflects stronger engagement of neural resources for conflict processing in negative emotional stimuli.

Participants varied in how fast they processed conflict and in how far emotion influenced conflict processing. Some of these differences could be explained by individual anxiety and depression levels, as well as temperamental effortful control. Participants high in effortful control solved conflict faster, which was reflected in a larger conflict N200 amplitude (for similar results see Gerardi-Caulton, 2000; Rothbart et al., 2003; Rueda, Rothbart, et al., 2005). Also, in participants scoring low in effortful control, conflict processing benefited less from emotional stimuli and showed no pronounced enhancement of the conflict N200 in emotional stimuli. The same pattern was found for conflict processing in emotional stimuli in participants scoring high in depression and anxiety. It may be that high sensitivity to emotional stimuli in high anxiety and depression participants, together with poor regulatory skills in emotion and attention leads to less appropriate evaluation of emotional stimuli regarding the organisms goals and therefore diminishes the supportive role emotion my have in guiding executive control of attention. This interpretation is supported by research with psychiatric patients showing overreactivity to emotional stimuli for example in post-traumatic stress disorder, anxiety disorders, and depression (for reviews see Drevets, 2001; Bar-Haim et al., 2007; Etkin & Wager, 2007).

In summary, the main question of the experiment could be answered. A conflict effect was present, and was modulated by emotion as evidenced in RTs and N200. Two questions follow from this result, (1) is this effect restricted to negative emotional stimuli, and (2) what is the neural basis of it. These questions were addressed in Experiments 2 and 3, respectively.

7.5 Experiment 2: Conflict N200 and positive emotion

The previous experiment showed that attentional control is enhanced in reaction to negative emotional stimuli. A consequent question is whether such an effect is restricted to negative stimuli, or whether positive emotional stimuli can also influence executive attention.

The motivation for studying the influence of emotional stimuli on control of attention mainly comes from their character as signals of behavioral relevance (Somerville, Wig, Whalen, & Kelley, 2006). This is especially true for threatening stimuli which possess survival value, and which individuals perceive as emotionally negative. However, emotionally positive stimuli also signal relevance. A fast response to a food stimulus, e.g., may not be of such immediate importance for survival as a reaction to a snake, but in the long run it is still crucial for survival. A few studies provided evidence for early detection of positive emotional stimuli, including words (Schapkin et al., 2000; Kanske & Kotz, 2007), which also activate the amygdala (Hamann & Mao, 2002; Dougal et al., 2007; Lewis et al., 2007). A comprehensive meta-analysis of emotional amygdala activation even produced a larger effect size for positive compared to negative emotional stimuli (Sergerie et al., 2008). Some other studies, in contrast, found selective early amygdala effects for negative, compared to neutral and positive stimuli (e.g., Garolera et al., 2007). The hypothesis that positive emotional stimuli exert a similar influence on attentional control as negative stimuli is therefore justifiable, but a bit more uncertain than for the negative words.

The hypotheses for interindividual differences in effortful control, depression, and anxiety are also less clear. Experiment 1 showed an association of effortful control with the conflict main effect in RTs and N200 amplitude. In line with previous research this association is expected again, as it is independent of emotion (Rueda, Rothbart, et al., 2005). In contrast, deficient emotion processing in depression and anxiety has mainly been shown for negative, not for positive stimuli (Li et al., 2007, 2008). This may abolish the association of depression and anxiety with the interaction of emotion and conflict.

Thus, the main questions and hypotheses for Experiment 2 were:

1. Is attentional control enhanced in reaction to positive emotional stimuli. This should result in a reduced RT conflict effect and an enlarged conflict N200 in positive emotional trials.

2. Temperamental effortful control is associated with conflict processing. However, subclinical depression and anxiety may show no relation to an influence of positive emotion on attentional control.

7.5.1 Methods

Participants. Twenty-six volunteers took part in the experiment, one participant had to be excluded because of too many artifacts in the EEG data. The remaining 25 (12 female) participants had a mean age of 23.7 years (SD 1.7). All participants were native speakers of German, right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean laterality quotient of 92.5 (SD 8.3), and reported normal or corrected-to-normal vision.

Task and materials. Participants performed the color flanker task described in Section 7.1 (see Figure 7.1). The words that were used were of positive and neutral valence (see Section 7.2).

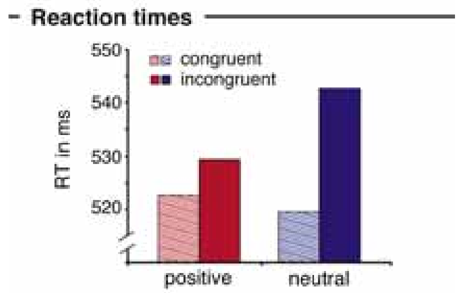

Figure 7.9: Reaction times in Experiment 2. Responses were slower in incongruent compared to congruent trials. The effect was modulated by emotion such that RTs in incongruent emotionally positive trials were reduced.

7.5.2 Results

Behavioral data. 97.4% (SD 3.5) of all trials were responded to correctly (RT mean = 528.5 ms, SD 81.2). There was a significant conflict effect; RTs were shorter for congruent compared to incongruent trials (see Figure 7.9 and Table 7.8; $F(1,24) = 10.6$, $P < .01$). Emotion did not have a significant effect on RTs, but the interaction of emotion and conflict was significant ($F(1,24) = 9.1$, $P < .01$). Follow-up analyses revealed that the conflict effect was only significant in neutral, not in positive trials ($F(1,24) = 16.0$, $P < .001$ vs. $F(1,24) = 1.9$, $P > .10$). This effect was driven by reduced RTs to positive incongruent trials, when compared to neutral incongruent

Word Condition	Congruent	Incongruent	Conflict
positive	522.6 (82.7)	529.3 (73.1)	6.7
neutral	519.5 (83.6)	542.6 (87.5)	23.1

Table 7.8: Reaction times in Experiment 2. Means and standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent trials.

trials (F(1,24) = 7.4, P < .05). There was no difference between positive and neutral congruent trials (F(1,24) = 0.58, P > .40).

Electrophysiological recordings. An N200 component starting around 190 ms with a larger amplitude for incongruent than congruent trials was observed. Figure 7.10 shows the difference waves of incongruent minus congruent trials for positive and neutral words. Repeated measures analyses on the mean amplitude between 190 and 250 ms yielded a marginally significant effect of conflict (F(1,24) = 4.0, P < .10). The effect was significant over anterior electrode sites, but not over posterior sites (F(1,24) = 7.8, P < .01 vs. F(1,24) = 0.7, P > .40, respectively). Also, there was a significant interaction of emotion, conflict, and region (F(1,24) = 7.2, P < .01). Follow-up analyses showed that the emotion by conflict interaction was only significant over anterior sites (F(1,24) = 8.5, P < .01, vs. (F(1,24) = 0.1, P > .90), where the conflict effect was significant for positive, but not for neutral trials (F(1,24) = 16.0, P < .001 vs. F(1,24) = 0.1, P > .70). There was no conflict N200 for positive or neutral trials over posterior sites (F(1,24) = 0.7, P > .40 vs. F(1,24) = 0.4, P > .50).

Correlational data. As in Experiment 1, effortful control negatively correlated with RT conflict, i.e., participants scoring high in effortful control showed smaller conflict effects (see Table 7.9). Effortful control was also negatively correlated to the interaction of emotion and conflict. Those participants with high effortful control showed an especially small conflict effect in negative compared to neutral trials. Depression, anxiety, and stress were not related to any conflict measure.

7.5.3 Discussion

The present study replicated the conflict main effect of Experiment 1. Also, emotionally positive stimuli decreased this conflict effect in RTs. A conflict N200 was enhanced in positive stimuli.

Temperamental effortful control was associated with faster conflict resolution, also in positive emotional trials, whereas individual scores in depression and anxiety were not related to the effect of positive stimuli on executive attention.

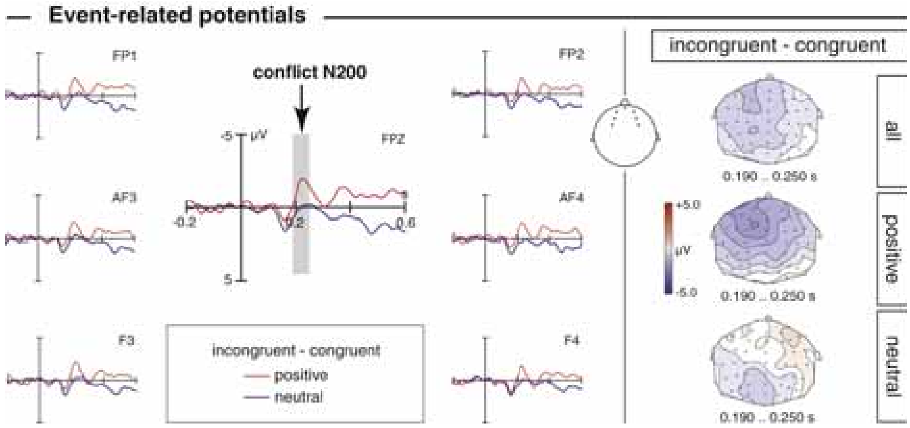

Figure 7.10: Event-related potentials in Experiment 2: Difference waves and difference maps for incongruent - congruent trials in the N200 time-window.

The main question that the present experiment aimed at was whether positive emotional stimuli would show effects on executive attention that are similar to the effects of negative emotional stimuli. This seems to be the case. The conflict effect in positive stimuli was reduced to less than 7 s, as compared to 21 s in negative trials in the previous experiment (which rendered it non-significant). However, there were also general differences in RTs between the participants of the two experiments, which make a direct comparison of the amount of RT conflict decreases difficult. In the behavioral control study, where both negative and positive stimuli were presented in one experiment, the reduced conflict scores were significant for for both types of emotional stimuli, numerically the reduction was even larger in negative trials. The question whether these subtle differences in the effects of negative and positive words are reliable needs further investigation. However, it seems clear that attentional control is not only enhanced in reactions to negative, but also to positive stimuli.

The first indices of such an influence in the event-related potential are again on the N200 which was observed in the same time-window as in Experiment 1 between 190 and 250 ms poststimulus. The conflict N200 was enhanced in positive as compared to neutral trials. The reduced behavioral conflict and enhanced conflict N200 corroborate the interpretation of the

	RT		Anterior N200	
	Conflict	Emotion Conflict	Conflict	Emotion Conflict
effortful control	-.41*	-.43*	-.46*	-.48*
depression	.16	-.13	.17	-.25
anxiety	.11	.17	.00	-.29
stress	-.04	-.25	.05	.02

Table 7.9: Correlations in Experiment 2: Pearson correlation coefficients of effortful control, depression, anxiety, and stress with RT and ERP effects. As described in Chapter 6, conflict refers to the conflict main effect (incongruent - congruent), and emotion conflict to the interaction of emotion and conflict (conflict in positive trials - conflict in neutral trials). *<.05; **<.01

N200 as an index of engaged neural resources during conflict processing. As suggested in the discussion of Experiment 1, emotion seems to trigger stronger engagement, or engagement of more neural resources for conflict processing[2]. This seems to be a fast process as the interaction already onsets at around 190 ms poststimulus presentation. It indicates that, similar to negative emotional stimuli, positive emotional stimuli are detected rapidly and henceforth can exert an influence on attentional control. This is in line with a few studies finding early ERP and amygdala effects for positive emotional words (e.g., Schapkin et al., 2000; Hamann & Mao, 2002).

If the effect of emotional stimuli on executive attention is, at least partly, due to these stimuli acting as relevance signals, it implies that positive and negative stimuli are similarly salient in that regard. However, while the behavioral relevance of negative emotional stimuli is unquestioned in the literature, especially for threat and consequent fear, it seems to be less apparent for positive stimuli (Ohman, Carlsson, Lundqvist, & Ingvar, 2007; LeDoux, 2007). Nevertheless, additionally to the evidence from early detection of positive emotion, patient data also suggest a strong behavioral relevance of positive emotional stimuli. In anxiety disorders, e.g., fear takes over and dominates perception and action. The powerful impact that positive emotional stimuli may have on behavior is most obvious in disorders such as addictions or binge eating (Koob, 2006). Patients with these disorders show a deficiency in appropriate evaluation of positive emotional stimuli. Verdejo-García, Bechara, Recknor, and Pérez-García (2006), e.g.,

[2]As described in Chapter 1, the EEG does not allow direct conclusions about the neural basis of observed scalp potentials. Nevertheless, usually it is a change in the scalp distribution that is interpreted as a change in the number or location of the generators. Note, however, that the reverse, a change in number or location of the generators must be followed by a change in scalp distribution, is not necessarily true.

reported that disinhibition in substance addicts is related to the perception of positive emotional images as highly arousing.

Consequently, the present experiment showed no relation of individual anxiety and depression scores to any of the conflict measures or to the influence of positive emotion on conflict. However, as in the previous experiment, effortful control was associated with faster conflict resolution (see also Gerardi-Caulton, 2000). Interestingly, participants high in effortful control also showed a stronger decrease in conflict RTs in positive emotional stimuli, accompanied by an N200 increase. As effortful control is related to emotion regulation, this indicates that participants with high regulatory skills in attention better use positive and negative emotional signals to adjust executive control of attention.

No effect was observed in the error rates. The reasons are probably the same as in the previous experiment in which accuracy was identically high. If performance was at ceiling, error rates were not variable enough to show effects of the experimental factors.

The present experiment aimed at answering the question whether an influence of emotion on attentional control is restricted to negative emotional stimuli. In RTs and the N200 amplitude, the experiment clearly demonstrated that positive stimuli can also have such an effect. Another question is whether it is possible to be more specific about the underlying neural basis. This question is addressed in the next experiment.

7.6 Experiment 3: Conflict and negative emotion in the ACC

The two previous experiments showed that attentional control is enhanced in reaction to emotional stimuli. A modulation of executive attention seems to take place already around 200 ms poststimulus presentation as the N200 amplitude increases. Such an increase in the amplitude of the component could be interpreted as stronger engagement, or engagement of more neural resources in conflict processing. The question if this really is the basis of the observed enhancement of conflict RTs and conflict N200 amplitudes can be adequately addressed with fMRI. Experiment 1 was therefore adapted to an fMRI study.

As described above (see Section 2.3), the N200 component has been localized in the ACC (Veen & Carter, 2002b). It is therefore expected that the ACC is involved in conflict processing, which was confirmed by numerous neuroimaging studies (for a recent meta-analysis see Nee et al., 2007). It is the dorsal portion of the ACC that is mainly found to be activated by incongruent stimuli, even though the exact locations of the activation peaks vary (see Figure 2.2, p. 22). The ventral ACC is activated by different types of emotion involving tasks, including emotional conflict resolution (e.g., Etkin et al., 2006). The present design does not involve emotional conflict, but conflict in emotional stimuli. An interesting question therefore is whether the subdivisions of the ACC are differently activated by conflict per se and conflict in emotional stimuli.

The ventral ACC receives input from the amygdala, which is also activated by emotional stimuli including emotional words (e.g., Hamann & Mao, 2002). Other studies demonstrated that activation of the amygdala can occur very shortly after stimulus presentation (e.g., in patients with intracranial electrodes, Landis, 2006). The present experiment could show whether emotional words used in the previous experiment activate the amygdala. This would strengthen the claim that the influence of emotion on executive attention is based on rapid emotion detection, possibly in the amygdala.

As in Experiment 1, effortful control, anxiety, and depression should be related to the observed effects. Participants scoring low in effortful control, or high in anxiety and depression, showed a less pronounced decrease in the RT conflict effect in emotional stimuli, and a smaller N200 amplitude increase. Therefore, they may also show less engagement of neural resources in conflict in emotional stimuli. In contrast, the amygdala has been shown to be overreactive in anxious and depressed participants, which may also affect amygdala activation in the present experiment (Siegle et al., 2007; Lee et al., 2007).

In summary, the present experiment addressed the following questions and hypotheses:

1. The RT conflict effect and the interaction of conflict and emotion shown in Experiment 1 should be replicated.

2. Conflict is expected to activate the dorsal ACC. The ventral ACC may be sensitive to emotion and conflict.

3. The amygdala should be active for emotional words, but not for conflict.

4. Individual scores in effortful control, subclinical depression, and anxiety may explain differences between participants in their reactions to conflict in emotional stimuli.

7.6.1 Methods

Participants. Twenty volunteers (10 female) were invited to the experiment. Mean age was 24.3 (SD 2.5). All participants were native speakers of German and right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean LQ of 94.6 (SD 9.4), and reported normal or corrected-to-normal vision.

Task and materials. Participants performed the color flanker task described in Section 7.1 (see Figure 7.1). The words that were used were of negative and neutral valence (see Section 7.2).

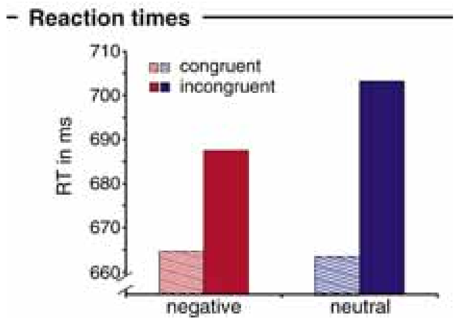

Figure 7.11: Reaction times in Experiment 3. Responses were slower in incongruent compared to congruent trials. The effect was modulated by emotion such that RTs in incongruent emotionally negative trials were reduced.

Word Condition	Congruent	Incongruent	Conflict
negative	664.7 (78.6)	687.6 (86.7)	22.9
neutral	663.4 (80.3)	703.2 (96.5)	39.8

Table 7.10: Reaction times in Experiment 3. Means and Standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent conditions.

7.6.2 Results

Behavioral data. The results resemble those from the ERP experiment using the same material (see Section 7.4). Overall accuracy was 95.6% (SD 4.2). Mean RTs were 679.7 ms (SD 84.7). The ANOVA yielded a significant main effect of conflict ($F(1,19) = 16.1$, $P < .001$). Congruent trials were responded to faster than incongruent trials (see Figure 7.11 and Table 7.10). There was an interaction of conflict and emotion ($F(1,19) = 4.6$, $P < .05$). Follow-up analyses revealed a reduced conflict effect for emotionally negative compared to neutral trials ($F(1,19) = 7.9$, $P < .05$, $\omega^2 = 0.15$ vs. $F(1,19) = 18.2$, $P < .001$, $\omega^2 = 0.30$). As in the ERP experiment, the effect was driven by reduced RTs in the emotional incongruent condition compared to the neutral incongruent trials ($F(1,19) = 4.9$, $P < .05$), while the difference between negative and neutral trials was not significant in the congruent condition ($F(1,19) = 0.0$, $P > .80$).

fMRI recordings. Table 7.11 shows those areas that were more activated for incongruent than congruent trials. These include the left and right ventral portion of the ACC (see Figure 7.12). Activations were also found in the left dorsal ACC and in the right dorsal ACC. For these activations, a time-line statistic was conducted averaging BOLD signal change (in %) from 5 to 9 s poststimulus for all voxels in the cluster. For the dorsal regions of the ACC there was a main effect of conflict (right: $F(1,19) = 30.4$, $P < .0001$; left: $F(1,19) = 20.4$, $P < .001$), but neither an effect of emotion, nor an interaction. For the ventral part of the ACC, however, a main effect of conflict was found (right: $F(1,19) = 16.4$, $P < .001$; left: $F(1,19) = 20.9$, $P < .001$) as well as an interaction of emotion and conflict (right: $F(1,19) = 4.4$, $P < .05$; left: $F(1,19) = 8.8$, $P < .01$), showing that the ventral ACC was more activated by negative incongruent (right: $F(1,19) = 18.7$, $P < .001$; left: $F(1,19) = 19.7$, $P < .001$) than neutral incongruent trials (right: $F(1,19) = 0.6$, $P > .40$; left: $F(1,19) = 3.43$, $P > .05$) when compared to the corresponding congruent condition (see Figure 7.12).

The amygdala was found to be activated for negative as compared to neutral words (see Figure 7.13; right: x = 19, y = -8, z = -12; Cs = 108; Z = 2.61; left: x = -16, y = -8, z = -12; Cs = 135; Z = 2.61). The time-line statistic (4 to 8 s poststimulus as the BOLD response peaked earlier than in the ACC regions) yielded a significant effect of emotion (right: $F(1,19) = 5.8$, $P < .05$; left: $F(1,19) = 5.9$, $P < .05$), but no effect of conflict or an interaction.

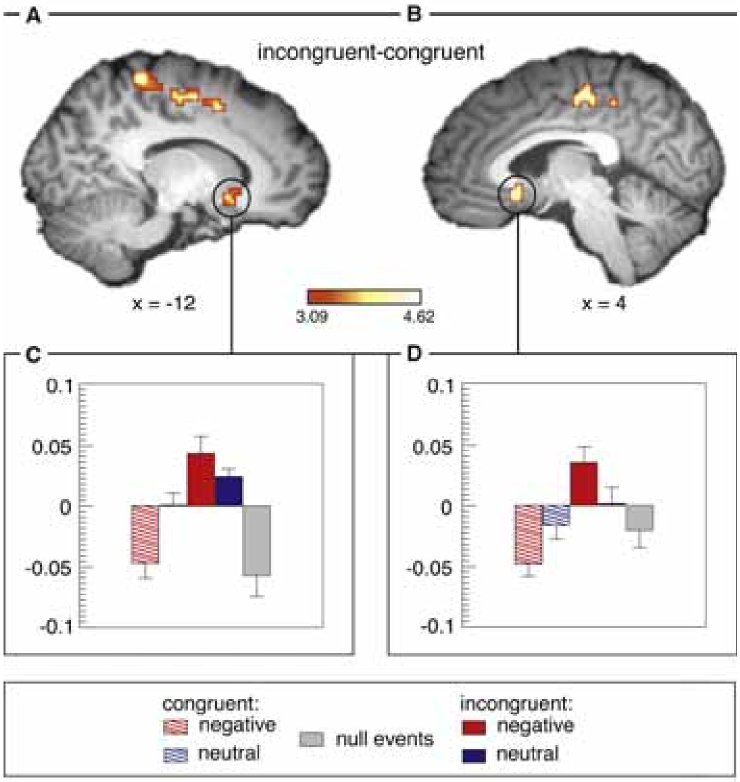

Figure 7.12: Left (A) and right (B) anterior cingulate activations in Experiment 3. Mean BOLD signal change (in %) is displayed for the left (C) and right (D) ventral anterior cingulate cortex.

Correlational data. Table 7.12 shows the correlations of effortful control, depression, anxiety, and stress with the behavioral conflict and emotion conflict effect. Here, the results from the EEG experiment were replicated, except for the correlation of effortful control and RT conflict, which was only marginally significant. Table 5 also shows the relation of the scales with the conflict and emotion conflict effect in the ventral ACC. Participants scoring high in effortful

Incongruent - Congruent	H	x	y	z	Cs	Zmax	BA
dorsal ACC	L	-8	-5	51	756	3.46	24
	L	-11	7	44	513	3.36	24
	R	6	17	44	1296	3.38	32
ventral ACC	L	-9	16	-9	459	3.41	32
	R	7	19	-9	1026	3.57	32
postcentral gyrus	L	-15	-36	60	702	3.64	3
	R	36	-24	45	513	3.27	3
precentral gyrus	L	-42	-3	36	378	3.30	6
	L	-42	-15	27	297	3.32	6
cuneus	R	30	-84	30	2646	3.38	19
middle occipital gyrus	L	-33	-87	21	864	3.39	19
inferior occipital	L	-36	-75	-3	459	3.32	19
fusiform gyrus	R	36	-66	-9	324	3.39	19
superior temporal gyrus	R	60	-18	0	513	3.57	22

Table 7.11: Activation foci related to conflict processing in Experiment 3. Incongruent vs. congruent BOLD response. H hemisphere; Cs cluster size in mm^3; BA Brodmann area

control showed a larger difference in the ventral ACC activation for incongruent compared to congruent items than low effortful control participants. This correlation was only marginally significant in the right hemisphere. High scoring effortful control participants also showed an enlarged emotion conflict effect compared to low effortful control participants. Depression and anxiety were not related to conflict contrasts, but showed the opposite pattern than effortful control for emotion conflict. Also, participants high in depression and anxiety activated the amygdala in response to negative words more than low depression and anxiety participants.

7.6.3 Discussion

To investigate the neural basis of emotion and executive control of attention, the flanker conflict effect was tested in emotional and neutral word stimuli. The RT conflict effect was reduced in emotional trials, suggesting that executive attention benefits from emotion, replicating the results from Experiment 1. The dorsal ACC showed a main effect of conflict, whereas the ventral ACC was sensitive to conflict only in emotional stimuli. The ventral ACC activation for conflict in emotional trials may result from input from the amygdala, which was activated by negative words. Interindividual differences in conflict processing and reactivity to emotional stimuli can be partly explained by anxiety and depression levels as well as temperamental effortful control.

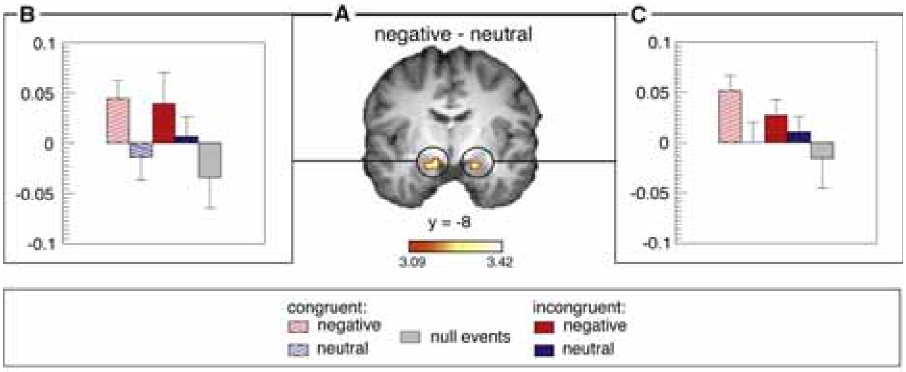

Figure 7.13: Left and right amygdala activations (A) in Experiment 3. Mean BOLD signal change (in %) is displayed for the left (B) and right (C) amygdala.

The amygdala is specialized in rapid detection of emotional valence from different types of stimuli, including emotional words (Sergerie et al., 2008; Zald, 2003). Amygdala activation was observed for negative compared to neutral words. This suggests that the amygdala was able to pick up the emotional significance of the presented words even though they were not task relevant. The fMRI data is not informative regarding the time-course of activation, but previous experiments with intracranial electrodes in the amygdala, or source localization with MEG, support the interpretation of amygdala activation as fast detection of emotional signals (Landis, 2006; Garolera et al., 2007). Also, even though clearly not reflecting amygdala activation itself, effects of emotional words on the P1 of the ERP were interpreted as basing on a fast emotion detection mechanism in the amygdala (Li et al., 2007, 2008). Therefore, amygdala activation for negative emotional words in the present study may be the basis of the rapid influence of emotion on the conflict N200.

Amygdala activation was not modulated by conflict. There are no reports showing that the amygdala is sensitive to conflict per se. Nevertheless, Etkin et al. (2006) observed amygdala activation for emotionally ambiguous stimuli (e.g., a fearful face with the word happy superimposed) compared to emotionally congruent stimuli (e.g., a fearful face with the word fear superimposed). In the present study, however, no emotionally incongruent stimuli were presented, the observed activation in the amygdala to emotional stimuli, irrespective of conflict, is therefore the most plausible result.

	RT		Conflict		Emotion Conflict		Emotion	
		Emotion	vACC		vACC		Amygdala	
	Conflict	Conflict	L	R	L	R	L	R
effortful control	-.43#	-.45*	.58*	.39#	.45*	.45*	.31	.12
depression	-.13	.45*	.15	.32	-.47*	-.52*	.46*	.49*
anxiety	-.16	.47*	.17	.33	-.45*	-.49*	.46*	.51*
stress	.19	-.20	.16	-.19	-.16	-.15	.22	-.17

Table 7.12: Correlations in Experiment 3: Pearson correlation coefficients of effortful control, depression, anxiety, and stress with RT and fMRI activations. As described in Chapter 6, conflict refers to the conflict main effect (incongruent - congruent), and emotion conflict to the interaction of emotion and conflict (conflict in negative trials - conflict in neutral trials). #<.10; *<.05; **<.01; vACC = ventral anterior cingulate cortex, L = left, R = right

Through strong connections the amygdala sends information to the ventral ACC (Vogt, Finch, & Olson, 1992; Devinsky et al., 1995). This region has been shown to be involved in conflict processing when stimuli are emotional (Etkin et al., 2006; Egner et al., 2008), whereas the dorsal portion of the ACC is activated by “cognitive conflict“ (Nee et al., 2007). This distinction is apparent when observing the peak activations from the cognitive and emotional conflict imaging studies depicted in Figure 2.2 on p. 22. Activation in the dorsal portion of the ACC was stronger for incongruent than congruent trials, irrespective of the emotion of the words. This result corroborates the view of the ACC as an important part of the executive attention network (Posner & DiGirolamo, 1998). The dorsal ACC thereby shows the opposite reaction pattern as the amygdala, whereas the ventral ACC seems to integrate emotional and conflict information. The ventral part of the ACC was also activated by conflict, but only when conflict was elicited by emotionally negative stimuli. This suggests that the ventral ACC may be additionally recruited for conflict processing when being signaled emotional relevance by the amygdala, yielding a reduced RT conflict effect. It may also be the basis of the enlarged N200 potential in emotional trials. However, this claim is made with considerable caution with respect to the relatively deep activation foci (see Chapter 1).

Several other areas were active for incongruent compared to congruent trials, including the fusiform and precentral gyrus, potentially reflecting the complexity of the task. As described in Section 2.3.2, the ACC is usually not found activated in isolation. In contrast to some previous work, however, DLPFC or IFG were not part of the activation patterns. This strengthens the claim that the ACC is the most vital part of the executive attention network (Weissman et al., 2005).

The correlations between effortful control, depression, anxiety, and the RT data mainly replicated Experiment 1, except for the correlation between effortful control and RT conflict, which was only marginally significant. The individual scores in the scales were also correlated with the amount of activation in the ventral ACC and the amygdala. Participants low in effortful, or high in depression and anxiety showed less increase in conflict activation in the ventral ACC for emotional stimuli. This result is in line with these participants showing a reduced N200 and less RT conflict reduction in emotional trials. It also conforms with previous research showing that ventral ACC activation for emotional stimuli is absent in depression and anxiety. Mannie et al. (2008), e.g., showed ventral ACC activation to emotional stimuli in a control population, whereas individuals with family risk for depression, who showed no signs of depression themselves, did not activate the ventral ACC. The ventral ACC may be crucial for appropriate evaluation of emotional stimuli and consequent adaptation of behavior in emotional situations, which is deficient in depressed and anxious individuals. These participants, in the present experiment, also exhibited stronger amygdala activation for negative emotional stimuli (Siegle et al., 2007; Lee et al., 2007).

Further questions that arise at this point are, whether the effects described in the present and the previous two experiments generalize to different forms of conflict, and to a different sensory modality. The next chapter addresses these questions in a set of three auditory Simon experiments.

Chapter 8

Auditory experiments

Chapter 7 reported data from a variant of the flanker task with emotional stimuli. Executive attention was enhanced in emotional trials, an effect that was reflected in an enlarged conflict N200 and additional conflict activation in the ventral ACC. The main objective of the present chapter was to further probe the validity of this effect and its generalizability. Therefore, two major changes in the experimental design were implemented. (1) A different conflict paradigm was applied, namely the Simon task, which tests the effect of compatible and incompatible stimulus response mappings, in contrast to the congruence of target and flanker stimuli in the flanker task. (2) Stimuli were presented in a different sensory modality, namely auditory, not visual. The claims that have been made about an emotional modulation of attentional control are independent of these two manipulations, thus the main results should be found again.

This chapter is organized largely analogously to the previous chapter. It starts with a general description of the experimental design that was applied in all auditory experiments, which is a variant of the Simon task with emotional stimuli (Section 8.1). Section 8.2 includes a description of how the stimuli were constructed and rated. In the following three sections the particular methodological parameters and results of two EEG and one fMRI study are delineated. Section 8.3 describes the ERP effects of negative words, whereas Section 8.5 contains an fMRI experiment on the neuroanatomical basis of these effects. The influence of positive emotional words is subject of an EEG experiment described in Section 8.4.

8.1 Auditory paradigm

The auditory design should retain the major characteristica of the visual experiments, which are (1) the presence of congruent and incongruent stimuli, and (2) presentation of emotional and neutral target stimuli. This was obtained with a variant of the Simon task. As in the flanker task, the presented stimuli can vary on two dimensions, one of which is task-relevant. In the flanker task, these dimensions are the identity of the target and flanker stimuli. In the Simon task, it is the identity of a target stimulus, and its spatial location in relation to the required response. It makes use of the phenomenon that a specific spatial location is associated with a specific response tendency, e.g., a left sided presentation elicits a left-body side response tendency (for an example with hands, feet, and eyes see Leuthold & Schröter, 2006). Conflict arises when the identity of the target stimulus requires a different response than its spatial location (see also Section 2.2). Even though this clearly is a form of conflict, it is created differently compared to the flanker task. The Simon task can therefore appropriately test the validity of the effects described in the previous chapter.

Additionally, the Simon task can be easily adapted to auditory stimulus presentation, which allows testing the effects in a different sensory modality. This enables manipulation of the emotional stimuli, moving from visual word reading to listening to utterances made of the same words with additional prosodic information (see Section 3.3). Thus, a modification of how conflict is created and what the emotional stimuli look like is achieved, nevertheless, targeting the same questions as in the visual design.

The variant of the Simon task (Simon & Rudell, 1967) that was applied can bee seen in Figure 8.1. Participants performed a gender decision task on single words spoken by a female and a male speaker (see Appendix B for the exact instructions). The words were presented to one ear only and participants responded with a button press of the left or right hand, so that the presentation side could be congruent or incongruent with the response side. The spoken words were emotionally positive, negative, or neutral. However, here the prosody corresponded to the affective valence of the words in order to avoid incongruencies in affective meaning and prosody as reported by Kotz et al. (2008).

In contrast to the visual design, there is one caveat in the auditory paradigm that is unavoidable when using speech stimuli. In audition, the signal always consists of information over time. While the entire stimulus was present at one single point in time in the visual design, auditory stimuli unfold over time. In consequence, conflict is not immediately present, but only occurs once the gender of the speaker is identified. It remains to be seen how this influences participants responses. Previous auditory Simon studies mainly applied simple sinusoidal tones whose pitch had to be detected. This is not directly comparable to the more complex task at hand.

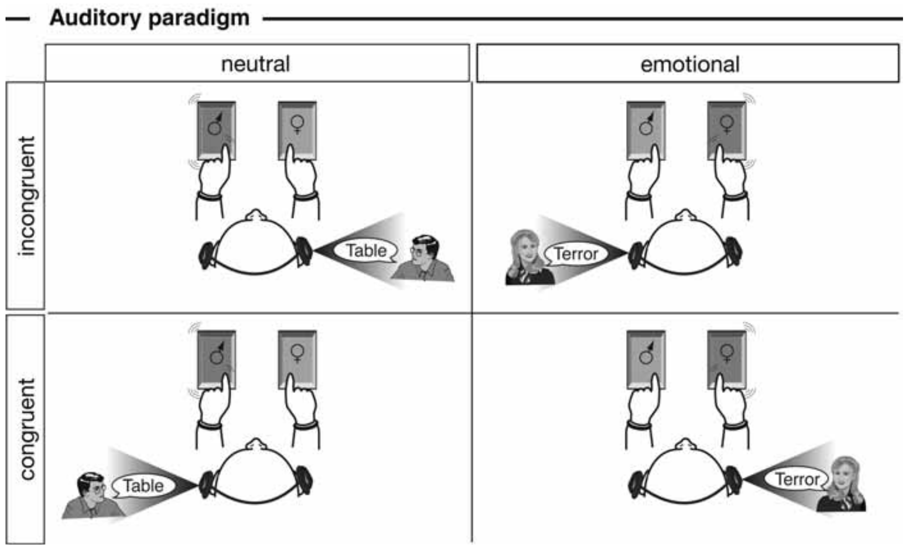

Figure 8.1: Auditory paradigm: Variant of the Simon task with emotional and neutral items. Participants determined the gender of the voice they heard, neglecting the presentation side when making their responses.

The experimental parameters were kept as close as possible to the visual experiments. Thus, one trial lasted 6000 ms. The onset of the stimuli was jittered between 0 and 2000 ms to avoid temporal orienting and, in the fMRI experiment, to allow for measurements at numerous time points along the BOLD signal curve, thus providing a higher resolution of the BOLD response (Miezin, Maccotta, Ollinger, Petersen, & Buckner, 2000). For the EEG experiments participants were seated in a comfortable chair in a sound-attenuated electrically shielded room and wore headphones (Sennheiser HD 202). In the fMRI experiment stimuli were presented via headphones that were specifically adapted for use in an fMRI scanner. A combination of external ear defenders and perforated ear plugs that conducted the sound directly into the auditory channel was used to attenuate the scanner noise without reducing the quality of speech stimulation. Volume was kept constant for all participants in each experiment. Mapping of responses to left and right response keys was counterbalanced across participants. Each stimulus was presented twice, once in the congruent and once in the incongruent situation. The number of trials is therefore twice the number of stimuli (see Section 8.2 for the details on the auditory stimulus sample). In the fMRI experiment 20 null events were added.

8.2 Auditory stimuli construction and rating study 2

To test the effect of emotion on attentional control in audition, auditory emotional stimuli were required. Of course there are numerous possible stimuli that could be used (such as vocalizations or emotional music); however, to keep the material close to the visual stimuli, the same words were employed, only that they were spoken. This allows control of all the lexical characteristics such as frequency of usage, that were controlled in the visual material. It raises one problem, however. Spoken language is always produced with certain prosodic characteristica that are perceived as emotional themselves (see Section 3.3 for a detailed description). Kotz et al. (2008) showed that a mismatch between emotional prosodic cues and the emotional meaning of the spoken material is perceived as a mild form of conflict. Thus, the words used in the present experiments were spoken in the corresponding emotional prosody. On the positive side this may add to the emotional salience of the stimuli; however, control of the stimuli becomes harder as emotional prosody is made up of differences in acoustic features. Control of all of these acoustic features would eliminate the emotional character of prosody. All words were spoken by actors, later the prosody was rated for emotional valence and arousal. The most unambiguously rated stimuli were chosen for the experiments.

8.2.1 Methods

Participants. Thirty participants (15 female) volunteered in the rating study. As in the previous rating study, handedness was not controlled as handedness should not influence ratings (Rodway et al., 2003). The mean laterality quotient according to the Edinburgh Handedness Inventory (Oldfield, 1971) was 87.8 (SD 20.4). All participants reported normal hearing.

Material. 120 words (see Chapter 7.2) consisting of 40 negative, 40 neutral, and 40 positive words were used in the auditory experiments. As described above, the word groups were controlled for concreteness, word frequency, number of letters and number of syllables (for word descriptives and statistics see Tables 7.1, 7.2, and 7.3). These words were spoken by professional actors who were native speakers of German. One of the speakers was female, the other male. They were told to express either anger for the negative words, happiness for the positive words, or no emotion for the neutral words. Recordings were done with Algorec 2.1 (Algorithmix GmbH, Waldshut-Tiengen, Germany) and the sound files were further processed with PRAAT (Institute of Phonetics Sciences, University of Amsterdam). To enable selection of appropriate stimuli for the main experiments, two versions of each positive, negative, and neutral word from each speaker were chosen for the rating study. Thus, participants of the rating were presented with 480 different auditory stimuli. To control for differences in loudness all stimuli were normalized in sound intensity to 75 dB SPL.

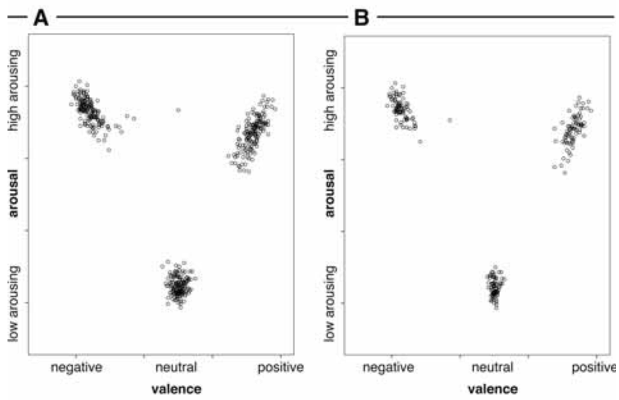

Figure 8.2: Scatter plots for valence and arousal ratings of the two versions of each of the 480 rated words (A) and the 240 selected words (B).

Procedure. Participants came to the lab to rate the words' valence (negative-neutral-positive) and arousal (high arousing-low arousing). The order of the tasks was counter-balanced. Rating was done on a 9-point scale. As in the visual rating, the Self Assessment Manikins (Hodes et al., 1985) were used for valence and arousal ratings (see Figure 7.2). Participants were instructed to evaluate word prosody (see Appendix B) for the exact instructions. The assignment of the scale endpoints to the left and right was counterbalanced across participants. Stimuli were presented via headphones (Sennheiser HD 202) at a comfortable sound intensity.

8.2.2 Results

As can be seen in Figure 8.2A almost all stimuli received distinct ratings in arousal and valence. From the two versions of each word, the one that had been rated most unambiguously for one condition (e.g., least arousing and most neutral for the neutral word condition) was chosen for the experiments (see Figure 8.2B). Thus, there were 40 negative, 40 neutral, and 40 positive words, each spoken by a male and a female speaker resulting in 240 stimuli in the experimental sample.

	Valence	Arousal	Duration	Mean Pitch	Max Pitch	Min Pitch
negative	2.3 (0.2)	7.4 (0.3)	0.6 (0.1)	280.8 (58.4)	361.6 (73.6)	179.6 (54.3)
neutral	5.0 (0.1)	2.4 (0.2)	0.6 (0.1)	159.7 (22.7)	191.9 (28.5)	124.0 (23.5)
positive	7.3 (0.2)	6.8 (0.4)	0.8 (0.2)	262.1 (52.2)	365.3 (87.0)	153.4 (34.7)

Table 8.1: Acoustic and rating specific descriptives for the selected words. Means and standard deviations (in parentheses) are given.

The descriptives for the auditory valence and arousal ratings are displayed in Table 8.1. Valence ratings of the three conditions differed significantly (see Tables 8.2 and 8.3). Interestingly, even though the arousal ratings of the visually presented negative and positive words did not differ, the negative words were slightly more arousing than the positive words. Both positive and negative words were significantly more arousing than neutral words. Naturally, the conditions also differed with respect to some of the acoustic parameters that constitute emotional prosody (see Chapter 3.3 for a detailed discussion of these characteristics). Note, however, that stimuli were normalized in intensity, thus loudness means are not reported.

Effect	*df*	*F value*	*p-value*
valence	2,237	12784.8	<.001
arousal	2,237	5170.6	<.001
duration	2,237	46.5	<.001
mean pitch	2,237	153.3	<.001
max pitch	2,237	170.7	<.001
min pitch	2,237	39.4	<.001

Table 8.2: Statistics for the selected words. The main effects of emotional word group (negative, neutral, positive) in valence and arousal ratings, as well as duration, mean, minimum, and maximum pitch are displayed.

8.2.3 Discussion

The well controlled sample of words that had been created in the previous rating (see Section 7.2) was spoken by professional actors in the corresponding emotional prosody. Based on valence and arousal ratings of the emotional prosody the better one of two versions of each spoken word was chosen for the experiments. This resulted in groups of negative and positive

	p-value					
Effect	Valence	Arousal	Duration	Mean Pitch	Max Pitch	Min Pitch
negative vs. neutral	<.001	<.001	>.90	<.001	<.001	<.001
positive vs. neutral	<.001	<.001	<.001	<.001	<.001	<.001
negative vs. positive	<.001	<.001	<.001	<.05	>.90	<.001

Table 8.3: Scheffé's multiple comparisons t test for the selected words. Contrasts were computed to specify the main effects in valence, arousal, duration, mean, minimum, and maximum pitch to whether negative, positive, and neutral words differed.

words that differed from neutral words in arousal and valence. Negative words were also slightly more arousing than positive words.

The valence and arousal ratings resulted, as in the visual rating, in a U-shaped function; however, with the intermediate stimuli missing. This indicates, that the actors intended emotional prosody for (most of) the auditory stimuli was easily recognized by the raters. Additionally, it is possible that participants in the prosody rating were influenced by the emotional meaning of the words. As only those words that had been selected for the visual experiments were used here, it is likely that a potential influence of emotional meaning on prosody ratings would have favored the pattern seen here. However, this is not problematic when using the stimuli in an experiment assessing the effect of emotion. On the contrary, the clear ratings of the "pure" emotional word meaning in the previous rating and the clear ratings of the prosody, or potentially a combination of prosody and meaning, demonstrate the quality and emotional salience of the selected words.

The fact that prosody ratings of positive emotional words were slightly less arousing than negative words unequivocally demonstrates that participants based their ratings mainly on the prosody, as such a difference was not present in the visual ratings. This arousal difference makes it harder to interpret potential differences in the effects of positive and negative stimuli. These differences may then be due either to valence or arousal of the stimuli. Nevertheless, the difference is only small, and positive words were still much more arousing than neutral words. As the arousal effect mainly comes from an increase in arousal for negative words (visual compared to auditory) and the arousal values for positive words are comparable between the two ratings, testing the effect of positive words on attention should still be possible.

As expected, the groups of words also differed in some acoustical characteristica. These variations are mainly in the direction expected from previous work on emotional prosody (see Section 3.3). Slight deviances are probably caused be the single word stimuli used in the present study. Most other researchers used phrases or entire conversations for their analysis which entail a stronger enunciative potential. However, the high recognition of the speakers intended emotion by the raters in the present rating demonstrates that emotional prosody can be expressed in single word utterances.

As for the visual rating, the sample of participants in the auditory rating was very similar to those invited for the main experiments. It is therefore assumed that the ratings generalize to those participants.

To summarize, the second rating study yielded a sample of emotional stimuli that can be used to study the effects of emotion on attention in audition.

8.3 Experiment 4: Conflict N200 and negative emotion

The present experiment is the counterpart to Experiment 1, as it also tests the effects of negative emotional words on executive attention in RTs and ERPs. The main differences are that the present experiment (1) applies a variant of the Simon task, and (2) presents stimuli in the auditory modality, which (3) adds negative emotional prosody to the emotional word meaning.

The Simon task has been shown to elicit conflict in audition and independent of the specific effector used (e.g., for hands, eyes, and feet, Leuthold & Schröter, 2006). It should therefore be a useful tool to investigate a potential interaction with emotion. The results regarding the conflict N200 are less clear, even though a few studies reported it for visual as well as auditory stimulation (Leuthold & Schröter, 2006; Carriero et al., 2007). Nevertheless, if the N200 indexes conflict processing as indicated by the visual experiments, it should also be elicited in the Simon task and its modification in emotional trials can be studied.

The salience of auditory emotional signals has been shown in several experimental paradigms. Grandjean et al. (2008) reported that emotional prosody can override neglect; Schirmer, Striano, and Friederici (2005) applied an MMN paradigm showing that the emotional prosodic stimuli are rapidly detected, and Brosch, Grandjean, et al. (2008) found that target detection was enhanced at locations that were cued with emotional prosody. Also, the amygdala seems to play a crucial role in detecting emotional prosody as this ability is deteriorated in patients with amygdala lesions (Scott et al., 1997). In addition, contrasting the "artificial" character of visual word presentation, prosody is potentially biologically prepared as an emotional stimulus.

The hypotheses regarding temperamental effortful control, depression, and anxiety are identical to those in Experiment 1.

The main questions and hypotheses, therefore, are:

1. Is conflict elicited in the auditory Simon task? Conflict would be reflected in prolonged RTs in incongruent compared to congruent stimuli. Also, a conflict N200 should be elicited by incongruent stimuli.

2. Is the effect of prosodically modulated emotional words on conflict processing comparable to the effect in visually presented emotional words? This should be reflected in reduced conflict RTs and enhanced conflict N200 amplitudes in incongruent stimuli.

3. Interindividual differences in effortful control, depression, and anxiety are associated to modulated attentional control in reactions to emotionally negative stimuli.

8.3.1 Methods

Participants. Twenty-six native speakers of German participated in the experiment, data from three participants had too be excluded because of too many artifacts in the EEG data. The remaining 23 (10 women) participants had a mean age of 25.1 years (SD 2.6). All participants were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean laterality quotient of 97.6 (SD 5.3), and reported normal hearing.

Task and materials. Participants performed the auditory Simon task described in Section 8.1 (see Figure 8.1). The words that were used were of negative and neutral valence (see Section 8.2).

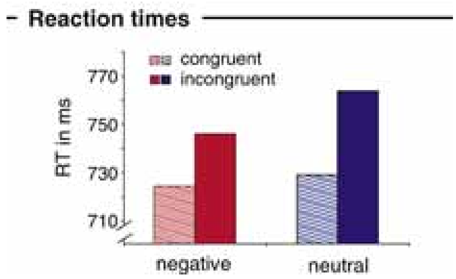

Figure 8.3: Reaction times in Experiment 4. Responses were slower in incongruent compared to congruent trials. The effect was modulated by emotion such that RTs in incongruent emotionally negative trials were reduced.

8.3.2 Results

Behavioral data. 99.7% (SD .6) of all trials were responded to correctly (RT mean = 740.8 ms, SD 129.6). There was a significant conflict effect; RTs were shorter for congruent compared to incongruent trials (see Figure 8.3 and Table 8.4; $F(1,22) = 17.6$, $P < .001$). Emotion did not have a significant effect on RTs, but the interaction of emotion and conflict was significant ($F(1,22) = 4.8$, $P < .05$). Follow-up analyses revealed that the conflict effect was smaller for negative compared to neutral trials ($F(1,22) = 8.6$, $P < .01$, $\omega^2 = 0.14$ vs. $F(1,22) = 22.4$, $P < .0001$, $\omega^2 = 0.32$). This effect was driven by reduced RTs to negative incongruent trials which were marginally different from neutral incongruent trials ($F(1,22) = 3.1$, $P < .10$). There was no difference between negative and neutral congruent trials ($F(1,22) = 0.6$, $P < .40$).

Electrophysiological recordings. A negative deflection starting around 420 ms with a larger amplitude for incongruent than congruent trials was observed. This potential mainly differed from the typical N200 (including the N200 in the visual experiments) in latency and duration. Therefore Figure 8.4A shows the original waveforms for incongruent and congruent trials. The ERPs of incongruent negative and neutral as well as congruent negative and neutral trials are displayed in Figure 8.4B. Repeated measures analyses of mean amplitudes between 420 and 550 ms yielded a significant main effect of conflict ($F(1,22) = 5.0$, $P < .05$). The conflict N200 was significant over anterior sites only and not over posterior sites ($F(1,22) = 5.5$, $P < .05$; $F(1,22) = 2.4$, $P > .10$, respectively). There was also an interaction of emotion, conflict, and region ($F(1,22) = 4.1$, $P < .05$). The interaction of emotion and conflict was only significant over anterior, but not over posterior electrode sites ($F(1,22) = 4.7$, $P < .05$ vs. $F(1,22) = 2.4$, $P > .10$). Over the anterior channels conflict was significant in emotional, but not in neutral trials ($F(1,22) = 13.1$, $P < .01$ vs. $F(1,22) = 0.1$, $P > .70$). There was no conflict N200 for negative or neutral trials over posterior electrodes ($F(1,22) = 2.6$, $P > .10$; $F(1,22) = 1.1$, $P > .30$).

Word Condition	Congruent	Incongruent	Conflict
negative	724.3 (139.2)	745.9 (136.9)	21.6
neutral	729.1 (120.7)	763.8 (125.8)	34.7

Table 8.4: Reaction times in Experiment 4. Means and standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent conditions.

Correlational data. Correlations with personality variables were largely comparable to the visual experiments. Effortful control was negatively correlated with RT conflict, i.e., participants scoring high in effortful control showed smaller conflict effects (see Table 8.5). Effortful control was also negatively correlated to the interaction of emotion and conflict. Those participants with high effortful control showed an especially small conflict effect in negative compared to neutral trials. Depression, anxiety, and stress were not related to RT conflict per se, but depression and anxiety showed a positive correlation with the interaction of emotion and conflict. Conflict resolution benefited less from emotional stimuli in individuals scoring high in depression and anxiety. Effortful control negatively correlated with the N200 conflict effect and with the N200 interaction effect. Participants with higher effortful control scores showed a larger N200 conflict

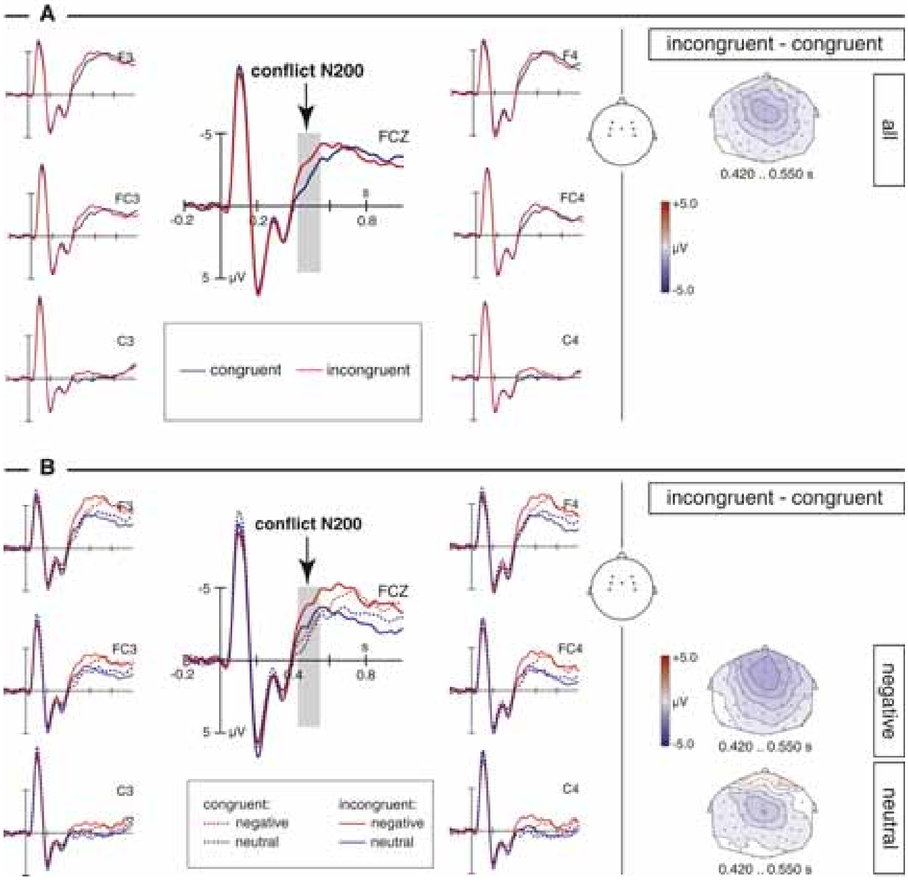

Figure 8.4: Event-related potentials in Experiment 4: Waveforms and difference maps for incongruent and congruent trials averaged over emotion (A) as well as for incongruent negative, neutral and congruent negative, neutral trials separately (B) are displayed.

response. This effect was larger in negative compared to neutral trials. Depression and anxiety showed the opposite effects. In summary, effortful control was related to efficient conflict processing and larger benefits from emotion in RTs and the N200. Depression and anxiety in contrast exhibited less benefit in conflict processing from emotion.

8.3.3 Discussion

To test the generalizability of attentional control in reactions to emotional stimuli, an auditory Simon task was applied presenting emotional target words. The effects largely resemble those from the visual experiment as RT conflict was reduced in emotional trials and the conflict N200 in the ERP was enhanced. Also, the correlations of effortful control, anxiety, and depression with these effects were replicated. The major differences to the visual experiment are the latencies of behavioral responses and of the N200 potential.

	RT		Anterior N200	
	Conflict	Emotion Conflict	Conflict	Emotion Conflict
effortful control	-.56**	-.47*	-.49*	-.45*
depression	.00	-.66**	-.14	-.65**
anxiety	.00	-.76**	-.12	-.53**
stress	-.13	.10	-.04	.15

Table 8.5: Correlations in Experiment 4: Pearson correlation coefficients of effortful control, depression, anxiety and stress with RT and anterior ERP effects. As described in Chapter 6, conflict refers to the conflict main effect (incongruent - congruent), and emotion conflict to the interaction of emotion and conflict (conflict in negative trials - conflict in neutral trials). *<.05; **<.01

The auditory Simon task proved to be an effective tool to study conflict processing. Participants consistently responded slower in incongruent stimulus-response mappings as compared to congruent trials. As in the visual flanker task, incongruent trials also elicited a negative deflection in the ERP. However, this potential occurred later in time and lasted slightly longer than the typical N200 response. The scalp distribution, in contrast, conforms extremely well with previous N200 reports (Veen & Carter, 2002b). Several factors suggest that the present experiment is not as sensitive to the timing of the conflict N200 as the visual design described earlier. In the flanker experiments, conflict is present from the onset of the stimuli on. In the present experiment, however, conflict only arises once the gender of the heard voice is identified. This can not happen at stimulus onset, part of the signal has to be presented first, thus it happens some time after stimulus onset. The delayed onset of the N200 may therefore be due to this delayed recognition. Furthermore, it may well be that the specific point in time at which gender is identified varies, probably not very much, but at least more than in the visual experiments. Such a jitter in the exact recognition points may have caused the N200 to show the prolonged duration. This interpretation fits nicely with the RT data which also showed longer latencies in responses, and greater variability. When comparing this numerically it is apparent that both, the onset of the N200 and the responses are prolonged for approximately 220/230 ms. Also, the standard deviation in RTs is roughly doubled, as is the duration of the N200. This supports the interpretation of the negative, conflict sensitive, deflection in the present experiment as an N200. The best control would of course be to conduct a gating experiment identifying the exact point in time at which the gender of the voice is recognized and then compute the ERP from this point in time on for each stimulus.

These issues prevent the unequivocal identification of the time-course of an interaction of emotion and conflict in the present experiment. The main question, however, could be addressed. The interaction described for the flanker design is found again, attentional control is enhanced in reactions to emotional stimuli which is also reflected in larger conflict N200 amplitudes. This indicates that processing of different forms of conflict, be it stimulus-response compatibility, or target-flanker stimulus congruency, is modulated by emotion.

The present experiment also demonstrated, that effects generalize to the auditory modality. The auditorily presented words, containing emotional prosodic cues and emotional meaning, were salient emotional stimuli influencing attentional control.

Generalizability is further strengthened by replication of the correlational pattern of temperamental effortful control, and the participants emotional state in depression and anxiety with the observed effects.

As in the visual experiments, no effects were observed on the error rates. The most likely reason for this lack of effects is that accuracy was even higher than in the visual experiments. Performance at ceiling probably made it impossible to show effects of the experimental manipulations.

It is therefore concluded that negative emotional stimuli can generally enhance executive control of attention. To also show these general effects for positive stimuli, Experiment 5 was conducted.

8.4 Experiment 5: Conflict N200 and positive emotion

In order to test the generalizability of the effects of positive emotional words on executive attention, the present experiment was conducted. It is therefore the equivalent to Experiment 2 from which it mainly differs in that (1) a Simon task was applied and that (2) stimuli were presented auditorily which (3) adds positive emotional prosody to the emotional signal.

The Simon task should elicit conflict with effects similar to those in Experiment 4. Of course, the same issue regarding the timing of the onset of conflict after stimulus presentation that was present in Experiment 4, applies to the present investigation. However, this should not affect the utility of the design to study the effects of positive emotion on attentional control.

The neural underpinnings of positive emotional prosody have only rarely been studied. Most studies that aimed at investigating the role of the amygdala in fMRI or in patients only presented fear, disgust, or anger prosody (Scott et al., 1997; Phillips et al., 1998; Sander et al., 2005; Quadflieg et al., 2008). Beaucousin et al. (2007) reported amygdala activation for emotional prosody, but do not differentiate between happy, angry, and sad stimuli. Kotz et al. (2003) separately looked at angry and happy prosody. They found similar fronto-temporal and subcortical activations for both, happy and angry prosody. In the EEG, early effects on the P2 were found for different positive and negative prosodic information (Paulmann & Kotz, 2008). It is therefore possible that positive emotional prosody in the present experiment does affect control of attention as indexed in the N200.

If the effects of positive emotional stimuli generalize to the present design, the correlational pattern with effortful control, subclinical anxiety and depression should also be found.

The major question and hypotheses were the following:

1. Can the effects of positive emotional words on executive attention be generalized to the auditory Simon task? In other words, is attentional control enhanced in reaction to positive emotional prosody in emotional words?

2. As in Experiment 2, temperamental effortful control should be associated with conflict processing, whereas depression and anxiety should show no relation to an influence of positive emotion on attentional control.

8.4.1 Methods

Participants. Twenty-six (14 female) native speakers of German participated in the experiment. Mean age was 24.5 years (SD 2.8). All participants were right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean laterality quotient of 96.7 (SD 6.6), and reported normal hearing.

Task and materials. Participants performed the auditory Simon task described in Section 8.1 (see Figure 8.1). The words that were used were of positive and neutral valence (see Section 8.2).

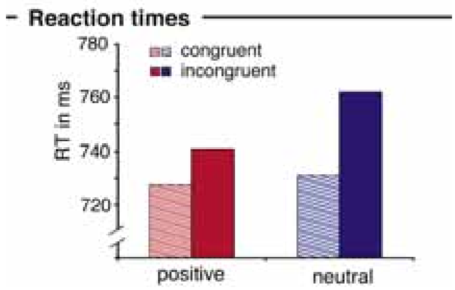

Figure 8.5: Reaction times in Experiment 5. Responses were slower in incongruent compared to congruent trials. The effect was modulated by emotion such that RTs in incongruent emotionally positive trials were reduced.

8.4.2 Results

Behavioral results. 99.2% (SD 2.7) of all trials were correctly responded to (RT mean = 738.1 ms, SD 147.0). There was a significant conflict effect; RTs were shorter for congruent compared to incongruent trials (see Figure 8.5 and Table 8.6; F(1,25) = 22.2, P < .0001). Emotion did not have a significant effect on RTs, but the interaction of emotion and conflict was significant (F(1,25) = 6.7, P < .05). Follow-up analyses revealed that the conflict effect was smaller for positive compared to neutral trials (F(1,25) = 5.3, P < .05, ω^2 = 0.08 vs. F(1,25) = 28.7, P < .0001, ω^2 = 0.35). This effect was driven by reduced RTs to positive incongruent trials which were significantly different from neutral incongruent trials (F(1,25) = 4.6, P < .05). There was no difference between positive and neutral congruent trials (F(1,25) = 0.2, P > .60).

Electrophysiological recordings. A negative deflection starting around 420 ms with a larger amplitude for incongruent than congruent trials was observed. Figure 8.6A shows the waveforms for incongruent and congruent trials. The ERPs of incongruent positive and neutral as well as congruent positive and neutral trials are displayed in Figure 8.6B. Repeated measures analyses of mean amplitudes between 420 and 550 ms yielded a significant main effect of conflict ($F(1,25) = 11.3$, $P < .01$). The conflict N200 was significant over anterior, but not over posterior electrode sites ($F(1,25) = 17.2$, $P < .001$ vs. $F(1,25) = 1.7$, $P > .20$). There was also an interaction of emotion and conflict ($F(1,25) = 13.6$, $P < .01$). Conflict was significant in emotional, but not in neutral trials ($F(1,25) = 27.6$, $P < .0001$ vs. $F(1,25) = 0.3$, $P > .50$). The interaction of conflict and emotion was significant over anterior and posterior electrode sites ($F(1,25) = 13.6$, $P < .001$; $F(1,25) = 5.9$, $P < .05$), yielding significant conflict effects for positive trials that were stronger over anterior than posterior sites ($F(1,25) = 34.6$, $P < .0001$, $\omega^2 = 0.40$; $F(1,25) = 5.4$, $P < .05$, $\omega^2 = 0.08$), but not for neutral trials ($F(1,25) = 1.6$, $P > .20$; $F(1,25) = 0.3$, $P > .50$).

Word Condition	Congruent	Incongruent	Conflict
positive	727.3 (152.8)	740.7 (162.1)	13.4
neutral	730.8 (131.4)	761.8 (128.8)	31.1

Table 8.6: Reaction times in Experiment 5. Means and Standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent conditions.

Correlational data. Effortful control negatively correlated with RT conflict, i.e., participants scoring high in effortful control showed smaller conflict effects (see Table 8.7). Effortful control was also negatively correlated to the interaction of emotion and conflict. Those participants with high effortful control showed an especially small conflict effect in positive compared to neutral trials. Depression, anxiety, and stress were not related to any conflict measure.

8.4.3 Discussion

The present experiment aimed at testing whether the effects of positive emotional stimuli on attentional control generalize to different forms of conflict and to another modality. To this end, happily spoken positive emotional words were presented in a gender decision Simon task. The results mainly resemble those from the corresponding visual experiment. RT conflict was reduced in emotional trials, the conflict N200 was enhanced. The correlational pattern of the effects with effortful control, depression, and anxiety was also found. The main differences concerned the latencies of responses and of the N200 potential.

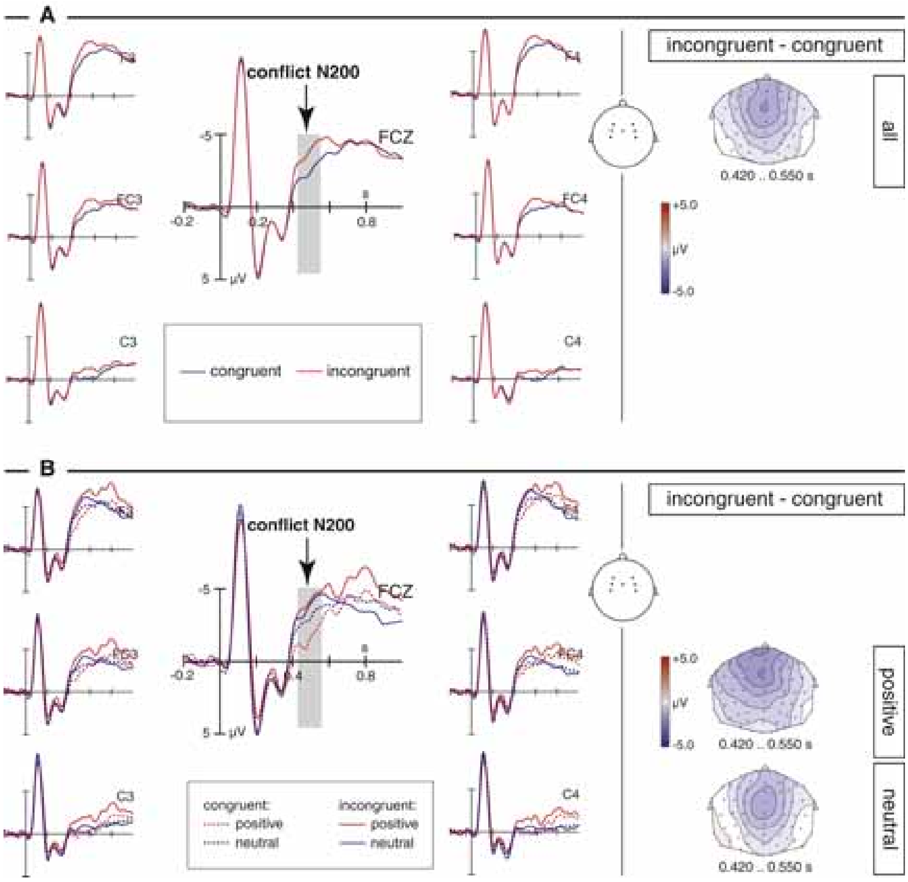

Figure 8.6: Event-related potentials in Experiment 5: Waveforms and difference maps for incongruent and congruent trials averaged over emotion (A) as well as for incongruent positive, neutral and congruent positive, neutral trials separately (B) are displayed.

The latency differences were also found in the previous experiment on the effects of negative auditory stimuli and are discussed there in detail. The same logic of delayed conflict elicitation applies to the present experiment. It is supported by very similar modulations in RT means and RT variability. Also, the scalp distribution of the potential very nicely matches earlier reports of the conflict N200 (Veen & Carter, 2002b). Despite the delayed latency of the negative potential it is therefore interpreted as a conflict N200.

This allows answering the major question of the present experiment. Positive emotional stimuli affect different forms of conflict, elicited by incompatible stimulus-response mappings, and incongruent target-flanker stimuli. This also generalizes to the auditory modality. The presence of such effects in auditory prosodically modulated stimuli supports previous evidence suggesting that positive prosodic cues may be salient and rapidly detected emotional signals (Paulmann & Kotz, 2008). It should be noted, however, that all effects represent a combination of emotional prosody and emotional word meaning. The aim of the study was not to isolate the prosodic effects.

	RT		Anterior N200	
	Conflict	Emotion Conflict	Conflict	Emotion Conflict
effortful control	-.46*	-.42*	-.47*	-.41*
depression	-.04	.28	.02	.19
anxiety	.21	.23	.18	-.10
stress	-.21	.22	.36	-.06

Table 8.7: Correlations in Experiment 5: Pearson correlation coefficients of effortful control, depression, anxiety, and stress with RT and anterior ERP effects. As described in Chapter 6, conflict refers to the conflict main effect (incongruent - congruent), and emotion conflict to the interaction of emotion and conflict (conflict in positive trials - conflict in neutral trials). *<.05; **<.01

Further support for a general interpretation of the relation of positive stimuli and attentional control comes from the replicated correlational pattern of the effects with effortful control, depression, and anxiety.

As in all previous studies, no effects were observed on error rates. Accuracy was very high in the present experiment, suggesting that performance at ceiling prevented observation of experimental effects.

The present experiment showed that the effects of positive emotional stimuli are generalizable to different forms of conflict and different sensory modalities. The next experiment asked whether the same neural basis underlies an emotional influence on processing different forms of conflict.

8.5 Experiment 6: Conflict and negative emotion in the ACC

The two previous auditory experiments showed that the enhancement of attentional control in reactions to emotional stimuli is independent of the exact task used and of the sensory modality of the stimuli presented. As in the visual experiments, the amplitude of the conflict N200 potential of the ERP was enlarged in emotional trials, suggesting engagement of more neural resources. Experiment 3 showed that the ventral ACC is additionally recruited for conflict processing when stimuli are emotional. The goal of the present experiment was to test whether the same brain areas underly an attentional modulation of conflict processing in the auditory Simon task.

The few studies that investigated brain activation in the Simon task mainly do report ACC activation (Peterson et al., 2002; Fan, Flombaum, et al., 2003). However, there is too little evidence to formulate concrete hypotheses about similarities and differences in Simon and flanker ACC conflict activations. In their extensive meta-analysis, Nee et al. (2007) were not even able to perform a separate analysis of Simon activations as there were not enough data points for this task. To the authors knowledge, there is no fMRI study applying an auditory Simon task yet. Nevertheless, the claims that were made about the ACC's role in conflict processing in general, and in the visual flanker study, strongly suggest that it is also active in incompatible stimulus-response mappings in the present auditory Simon task.

Experiment 3 suggested that the role of the ventral ACC may be to provide additional neural resources for conflict processing in emotional stimuli. If this is the case, than the ventral ACC should also be sensitive to stimulus-response incompatibility in emotional trials in the present experiment. Hints at such involvement come from a small number of studies on emotional conflict processing (e.g., Etkin et al., 2006).

A couple of experiments reported amygdala activity for emotional prosody (Phillips et al., 1998; Sander et al., 2005; Beaucousin et al., 2007; Quadflieg et al., 2008). As in Experiment 3, amygdala activity was therefore also expected in the present experiment when contrasting negative emotional stimuli with neutral words. Experiment 3 had raised the possibility that detection of emotional stimuli in the amygdala may be the basis of ventral ACC involvement in conflict processing in emotional trials. Such a claim would be strengthened if the amygdala was active for the auditory emotional stimuli as well.

Lastly, effortful control, anxiety, and depression were hypothesized to be similarly associated with conflict processing and an interaction with emotion as in the previous experiments.

The experiment, therefore, aimed at the following questions:

1. The RT conflict effect and the interaction with emotion that were observed in Experiment 4 should be replicated.

2. Similarly as in Experiment 3, the dorsal ACC should be activated by incongruent stimuli, while the ventral ACC division should be sensitive to the interaction of conflict and emotion.

3. Emotional auditory word stimuli may activate the amygdala.

4. Individual scores in effortful control, subclinical depression, and anxiety may explain differences between participants in their reactions to conflict in emotional stimuli.

8.5.1 Methods

Participants. Twenty-two volunteers (10 female) were invited to the experiment. Mean age was 24.7 (SD 2.7). All participants were native speakers of German and right-handed according to the Edinburgh Handedness Inventory (Oldfield, 1971) with a mean LQ of 98.0 (SD 4.3), and reported normal hearing.

Task and materials. Participants performed the auditory Simon task described in Section 8.1 (see Figure 8.1). The words that were used were of negative and neutral valence (see Section 8.2).

8.5.2 Results

Behavioral data. The results resemble those from the ERP experiment with the same material (see Section 8.3). Overall accuracy was a bit lower 93.0% (SD 3.8) which may be due to the scanner noise. However, accuracy was still high and there were no significant differences between conditions. Mean RTs were 828.8 ms (SD 172.9). The ANOVA yielded a significant main effect of conflict ($F(1,21) = 63.7$, $P < .0001$). Congruent trials were responded to faster than incongruent trials (see Figure 8.7 and Table 8.8). There was an interaction of conflict and emotion ($F(1,21) = 4.92$, $P < .05$). Follow-up analyses revealed a reduced conflict effect for

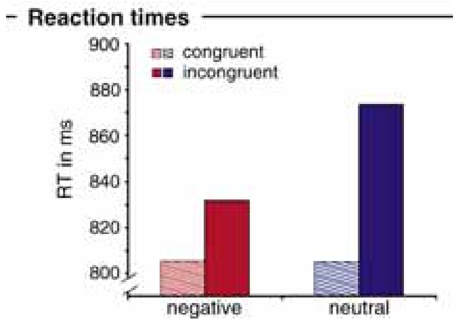

Figure 8.7: Reaction times in Experiment 6. Responses were slower in incongruent compared to congruent trials. The effect was modulated by emotion such that RTs in incongruent emotionally negative trials were reduced.

emotionally negative compared to neutral trials (F(1,21) = 4.4, P < .05, ω^2 = 0.07 vs. F(1,21) = 52.0, P < .0001, ω^2 = 0.54). As in the ERP experiment, the effect was driven by reduced RTs in the emotional incongruent condition compared to the neutral incongruent trials (F(1,21) = 9.1, P < .01), while the difference between negative and neutral was not significant in the congruent condition (F(1,21) = 0.0, P < .90).

Word Condition	Congruent	Incongruent	Conflict
negative	805.2 (153.5)	831.6 (181.6)	26.4
neutral	804.9 (185.9)	873.4 (174.8)	68.4

Table 8.8: Reaction times in Experiment 6. Means and Standard deviations (in parentheses) are given. The conflict effect is computed as the difference between incongruent and congruent conditions.

fMRI recordings. Table 8.9 shows those areas that were more activated for incongruent than congruent trials. These include the left and right dorsal portion of the ACC (see Figure 8.8). Also, activation of the right ventral ACC was found for conflict in the emotional context. For these activations a time-line statistic was conducted averaging BOLD signal change (in %) from 3 to 8 s poststimulus for all voxels in the cluster. For the dorsal regions of the ACC there was a main effect of conflict (right: F(1,21) = 28.9, P < .0001; left: F(1,21) = 38.6, P < .0001), but neither an effect of emotion, nor an interaction. For the ventral part of the ACC, however, a main effect of conflict was found (F(1,21) = 8.6, P < .01) as well as an interaction of emotion and conflict (F(1,21) = 5.7, P < .05), showing that the ventral ACC was more activated by negative incongruent (F(1,21) = 8.0, P < .01) than neutral incongruent trials (F(1,21) = 0.2, P > .60) when compared to the corresponding congruent condition (see Figure 8.8).

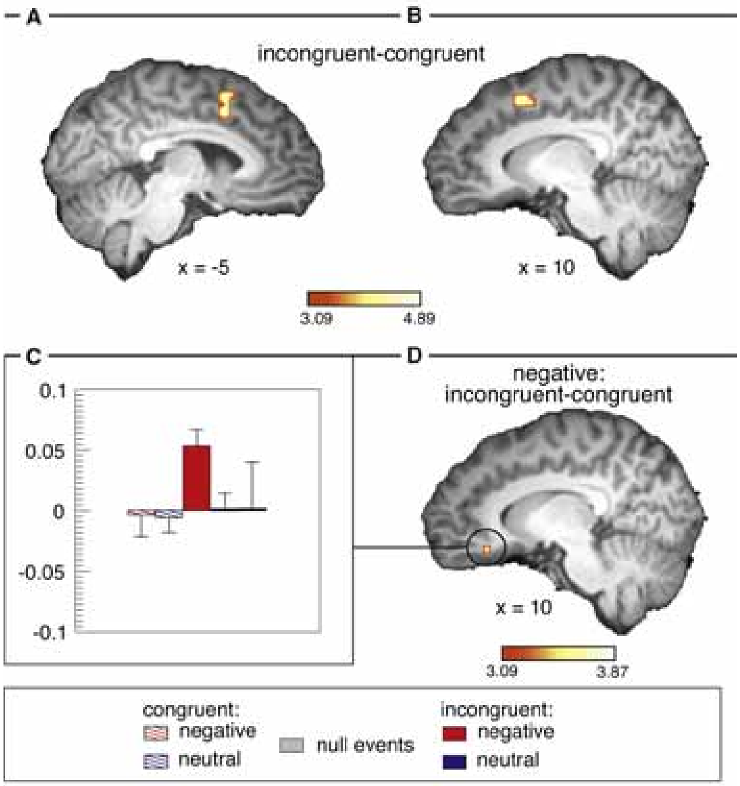

Figure 8.8: Left (A) and right (B) anterior cingulate activations for the contrast of incongruent - congruent trials in Experiment 6. The same contrast for negative trials yielded activation in the right ventral anterior cingulate cortex (D) for which the mean BOLD signal change (in %) is displayed (C).

The amygdala was bilaterally activated for negative as compared to neutral words (see Figure 8.9; right: x = 22, y = -9, z = -12; Cs = 189; Z = 2.40; left: x = -20, y = -10, z = -11; Cs = 180; Z = 2.64). The time-line statistic yielded a significant effect of emotion (right: F(1,21) = 4.4, P < .05; left: F(1,21) = 4.3, P < .05), but no effect of conflict or an interaction.

Correlational data. Table 8.10 shows the correlations of effortful control, depression, anxiety, and stress with the behavioral conflict and emotion conflict effect. Here the results from the EEG experiment were replicated. Table 8.10 also shows the relation of the scales with the emotion conflict effect in the ventral ACC. High scoring effortful control participants showed an enlarged

Incongruent - Congruent	H	x	y	z	Cs	Zmax	BA
dorsal ACC	L	-5	9	29		3.80	32
	R	10	11	43	1431	4.02	32
paracentral lobule	R	22	-43	45	270	3.61	5
superior temporal gyrus	R	64	-28	9	324	4.89	42
Negative:							
Incongruent - Congruent	H	x	y	z	Cs	Zmax	BA
ventral ACC	R	10	33	-12	675	3.17	32
Neutral:							
Incongruent - Congruent	H	x	y	z	Cs	Zmax	BA
middle frontal gyrus	L	-20	2	60	378	3.39	6
frontal sub-gyral	R	22	-4	54	675	3.41	6
middle front gyrus	R	28	2	39	297	3.41	6
superior temporal gyrus	R	64	-31	9	324	3.45	42

Table 8.9: Activation foci during conflict processing in Experiment 6. Incongruent vs. congruent BOLD response. H hemisphere; Cs cluster size in mm^3; BA Brodmann area

emotion conflict effect compared to low effortful control participants. Depression and anxiety showed the opposite pattern than effortful control for emotion conflict. Also, participants high in depression and anxiety activated the amygdala in response to negative words more than low depression and anxiety participants. This effect was only marginally significant in the left Amygdala.

8.5.3 Discussion

The present experiment aimed at investigating the neural basis of an emotional modulation of attentional control in an auditory Simon task. Conflict was elicited in incompatible stimulus-response mappings as evidenced in longer RTs, but was reduced in emotional trials. The dorsal portion of the ACC was activated in incongruent trials, whereas the right ventral ACC was sensitive to conflict only in emotional stimuli. Angrily spoken negative emotional words activated the amygdala. Participants' scores in effortful control, anxiety, and depression were associated with conflict processing and the enhanced performance in emotional trials. These results resemble those of Experiment 3 and 4, the main differences were prolonged RTs, slightly reduced accuracy, and right-lateralization of the ventral ACC activity.

RTs revealed a conflict effect that was reduced in emotional trials. This effect was significant even though the behavior showed some indices of general impairment. RTs were approximately

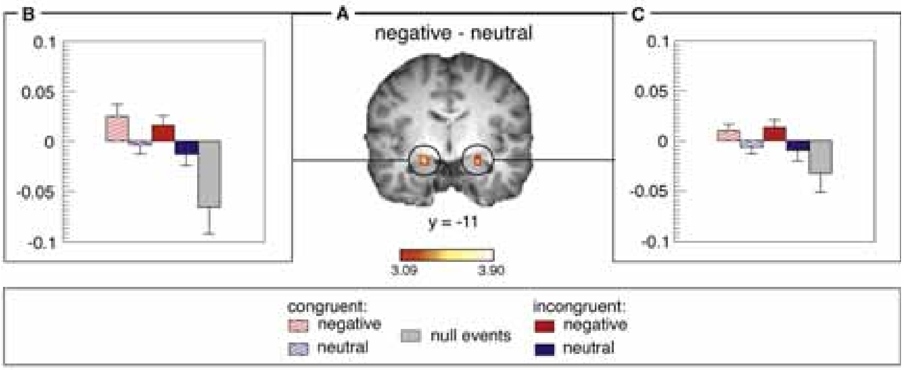

Figure 8.9: Left and right amygdala activations (A) in Experiment 6. Mean BOLD signal change (in %) is also displayed for the left (B) and right (C) amygdala.

90 ms longer than in the EEG experiment with the identical material, error rates were about 6% worse. This decline in performance was most probably caused by the scanner noise. This was not a problem in the previous fMRI experiment as stimuli had been presented visually; however, in the present experiment it seems to have resulted in decreased perceptional quality. Despite these difficulties, the experimental manipulations affected RTs in line with the hypotheses and the previous experiments. Therefore, brain activity in reaction to auditory stimuli should still be observable.

The amygdala activation for negative emotional stimuli resembles that obtained for visually presented negative words in Experiment 3. This is in line with a few earlier studies on emotional prosody that reported amygdala activity (Phillips et al., 1998; Sander et al., 2005; Beaucousin et al., 2007; Quadflieg et al., 2008), or deteriorated recognition of emotional prosody in patients with amygdala lesions (Scott et al., 1997; Sprengelmeyer et al., 1999). Also, it should be noted that the present experiment did not study "pure" prosody effects as the word meaning was emotional too. The observed amygdala activation was not modulated by conflict.

The opposite pattern was present in the dorsal part of the ACC. This region was activated by incongruent stimuli, but did not show any sensitivity to emotion. As in Experiment 3, the ventral ACC integrated both informations and was only activated in emotional and incongruent trials. However, in contrast to the visual experiment, activity was only observed in the right ventral ACC. The left ventral ACC was not activated. Also, the activation in the right ventral ACC was only observed for incongruent versus congruent trials when stimuli were emotional.

	RT		Emotion Conflict	Emotion	
		Emotion	vACC	Amygdala	
	Conflict	Conflict	R	L	R
effortful control	-.44*	-.53*	.51*	.21	-.04
depression	.33	.44*	-.43*	.38#	.46*
anxiety	.33	.43*	-.44*	.37#	.45*
stress	.02	.12	-.23	-.35	-.30

Table 8.10: Correlations in Experiment 6: Pearson correlation coefficients of effortful control, depression, anxiety, and stress with RTs and fMRI activations. As described in Chapter 6, conflict refers to the conflict main effect (incongruent - congruent), and emotion conflict to the interaction of emotion and conflict (conflict in negative trials - conflict in neutral trials). #<.10 *<.05; **<.01; vACC = ventral anterior cingulate cortex, L = left, R = right

One reason for the right lateralization of the ventral ACC activity may be the general right hemisphere dominance for emotional prosodic information (for a review see Schirmer & Kotz, 2006). The prominent prosodic manipulation in the auditory stimuli seems to have dominated the emotional character of the stimuli, overriding the emotional word meaning. Nevertheless, the amygdala did not show this pattern of lateralization. The question of lateralization should be addressed in future research.

The relation of effortful control, anxiety, and depression to the RT measures replicates the results in the earlier experiments with negative emotional material. Similarly, the results in the right ventral ACC for conflict in negative emotional stimuli resemble those obtained in the visual stimulation. Participants low in effortful control or high in depression or anxiety do not activate this region for conflict resolution in emotional stimuli as much. The amygdala activation for emotionally negative stimuli is sensitive to anxiety and depression levels in the participants as in Experiment 3. Interestingly, however, this relation was only significant in the right amygdala, marginal significance was obtained in the left amygdala. This may be a another hint at the right hemisphere dominance for emotional prosody.

In summary, the pattern of activity in the amygdala, and the ventral and dorsal ACC largely resembles the data from the visual flanker task, suggesting that the effect of emotion on attentional control is a general one, independent of the exact form of conflict or the sensory modality of stimulation.

Part III

General discussion

Chapter 9

Discussion

The present dissertation investigated executive control of attention in reaction to neutral and emotional stimuli. The collected behavioral, EEG, and fMRI data yielded a coherent pattern of findings that is summarized in the current chapter. Section 9.1 briefly reviews the main results of each experiment. Whether these provide an answer to the raised research questions is discussed in Section 9.2.

9.1 Summary

Two sets of experiments were conducted in which executive attention performance was tested in reaction to emotional stimuli. To achieve this, a variant of the flanker task was adapted in which three words were presented one above the other. Participants task was to identify the color of the central word, the flanker words were either in the same (congruent) or in a different (incongruent) color. Emotional and neutral words were used (e.g., peace, happy, kiss, or table). This allowed assessment of conflict processing in neutral and emotional stimuli.

A second set of experiments tested the generalizability of the findings to different forms of conflict and to a different sensory modality. A variant of the Simon task was used in which emotional words were presented auditorily to only one ear at a time. Participants identified the gender of the voice and responded with a right or left hand button press. Stimulus presentation side and response side could be the same (congruent) or different (incongruent). As the words presented were of emotional or neutral meaning and prosody, this design allowed assessment of processing stimulus-response conflict in neutral and emotional auditory stimuli.

Visual experiments

Stimulus construction and rating study 1. Visually presenting emotional words is advantageous to using emotional images or faces in that it allows control of a variety of factors including frequency of occurrence in everyday life and physical attributes such as brightness or complexity. Therefore, a large sample of 1000 words was collected for the present experiments. The words were rated in valence, arousal, and concreteness. Based on these ratings, as well as frequency of usage taken from the Leipzig Wortschatzlexikon (Biemann et al., 2004), and number of letters and syllables, subsamples of positive, negative, and neutral words were created. These differed in valence and arousal, but not in any other measure.

Behavioral control study: Attention effects of emotional words. The goal of this experiment was to validate the salience of the chosen emotional words before using them in a novel design. To this end, a task whose sensitivity to emotional stimuli had been shown before was adapted, namely the cueing paradigm (Stormark et al., 1995). The words were presented as cues, validly or invalidly predicting the target location. Target detection was enhanced after emotional valid cues and deteriorated after emotional invalid cues, which indicates that attention was oriented faster to the location of an emotional cue, and was captured there longer. This shows that the present selection of emotional words was well-suited for studying an emotional influence on attention.

Experiment 1: The conflict N200 and negative emotional words. Experiment 1 tested negative emotional words like ”war“ or ”murderer“ in the flanker task described above. Reaction times and ERPs were measured. Participants responded faster to congruent compared to incongruent stimuli. This behavioral conflict effect (incongruent - congruent) was accompanied by an N200 potential that was enlarged in incongruent trials. Such a replication of earlier flanker studies (Veen & Carter, 2002b) was the basis for studying an influence of negative emotion on executive attention. Interestingly, RT conflict was reduced in negative emotional stimuli which suggests that attentional control is enhanced in reactions to negative emotional stimuli. Also, the conflict N200 was enlarged in negative emotional trials. This is in line with earlier studies relating increased efficiency of conflict processing to larger N200 amplitudes, e.g., when executive attention is trained (Rueda, Rothbart, et al., 2005). It raises the possibility that more neural resources are engaged in conflict processing resulting in reduced RTs. This question is addressed in an fMRI study in Experiment 3.

Experiment 2: The conflict N200 and positive emotional words. Experiment 2 tested whether the findings of Experiment 1 are restricted to negative emotional words, or can also be extended to positive emotional words. The rapid influence of negative emotional stimuli on conflict processing already around 200 ms poststimulus is well-supported by findings of very early detection of negative emotion from word stimuli in EEG, MEG, and patients with intracranial electrodes in the amygdala (Landis, 2006). There is less evidence for positive emotional words; however, a few studies also report early effects here (Schapkin et al., 2000). Experiment 2 yielded a similar reduction in RT conflict for positive words, as that found for negative words in Experiment 1. Also, the conflict N200 amplitude was similarly enhanced. It may therefore be concluded that attentional control is enhanced in reaction to negative and positive emotional stimuli alike.

Experiment 3: ACC conflict activation and negative emotional words. The previous two experiments alluded to the possibility that additional engagement of neural resources for conflict processing in emotional stimuli is the basis of the enhanced behavioral performance. Experiment 3 applied fMRI to further test this question in negative emotional words. The behavioral effects of Experiment 1 were replicated. As in previous imaging studies, the dorsal ACC showed a main effect of conflict, being activated by incongruent compared to congruent stimuli (Nee et al., 2007). Interestingly, the ventral ACC displayed an interaction of conflict and emotion, this region was only activated for incongruent trials when stimuli were emotional. Such a dissociation of dorsal and ventral ACC activations is supported by cytoarchitecture and connectivity patterns of the two regions (Bush et al., 2000). The ventral ACC receives projections also from the amygdala which detects emotional signals early on (LeDoux, 2007). The amygdala was also activated in the present experiment in response to negative emotional words. In conclusion, the ventral ACC seems to integrate conflict and emotional information, providing neural resources for conflict processing in emotional stimuli.

Auditory experiments

Stimulus construction and rating study 2. To obtain auditory emotional stimuli, the well-controlled selection of words used in the visual experiments was spoken by professional actors in the corresponding emotional prosody. Thus, negative words were spoken angrily and positive words happily. This was done to avoid a mismatch of word meaning and prosody which creates mild forms of conflict (Kotz et al., 2008). The emotional prosody of each recorded word was rated in valence and arousal, showing that listeners easily identified the emotion intended by the speaker. The resulting samples of auditory words differed in some acoustical features that constitute emotional prosody (e.g., mean pitch).

Experiment 4: The conflict N200 and negative emotional words. Experiment 4 aimed at testing the effects of Experiment 1 with a different form of conflict and in a different sensory modality. Therefore, the emotional words were presented in an auditory Simon task. The results closely resembled those of Experiment 1, suggesting that enhancement of attentional control in reactions to emotional stimuli is a general phenomenon. The only major differences in the present experiment were prolonged latencies of behavioral responses and of the N200 component. These latency differences can be best explained by a difference in the experimental design. While in the visual flanker task, the onset of the stimuli is also the "onset of conflict", in the auditory Simon experiment, conflict only arises once the participants identified the gender of the voice and the corresponding response hand. This does not happen at stimulus onset, but sometime during stimulus presentation. Even though this makes it harder to interpret the time-course of conflict processing in the present experiment, it does not affect the main conclusion, that Simon-type conflict is processed faster in auditory emotional stimuli.

Experiment 5: The conflict N200 and positive emotional words. The goal of Experiment 5 was to test the generalizability of the findings obtained in Experiment 2. As for positive emotional visual words, investigations of positive emotional prosody are much more rare than the corresponding negative emotional counterpart (for an example on amygdala activation for negative emotional prosody see Sander et al., 2005). Nevertheless, very recent ERP evidence suggests that positive emotional prosody is also detected very rapidly (Paulmann & Kotz, 2008). Experiment 5 showed that the pattern of results for visual presentation of positive emotional material is also present for auditory positive emotional stimuli in the Simon task.

Experiment 6: ACC conflict activation and negative emotional words. This experiment tested whether the neural basis underlying enhanced attentional control in auditory emotional signals in the Simon task is the same as in the visual flanker task. Previous imaging studies using a Simon task are rare and applied only visual stimuli (see, e.g., Fan, Flombaum, et al., 2003). Nevertheless, the claims made about the role of the ACC in conflict processing suggest that its dorsal portion is also activated by Simon-type conflict, and that the ventral part is sensitive to this conflict in emotional stimuli. This is exactly what was found in the present experiment. Additionally, the amygdala was activated by emotional prosodically modulated words. The only major difference to the visual experiment was a right lateralization of the ventral ACC activation which corresponds well with other findings of a general right hemisphere involvement in processing emotional prosody (for a review see Schirmer & Kotz, 2006).

Interindividual differences. Lastly, individual temperamental effortful control, which describes the ability to regulate attention and is also associated with emotion regulation, as well as subclinical anxiety and depression were assessed in each experiment. The individual scores were correlated with the experimental effects yielding a very consistent pattern across the different experiments. As has been reported before, effortful control was associated with better performance in conflict processing (Rothbart et al., 2003). Also, participants low in effortful control, or high in depression or anxiety exhibited a smaller enhancement in executive attention in negative emotional stimuli. This included a reduced enhancement of the conflict N200 and of the ventral ACC activity. The consistency of these correlations across different samples, different conflict tasks, and different sensory modalities adds to the generalizability of the observed effects.

9.2 Implications

Chapter 5 raised eight questions that the experiments in this dissertation attempted to answer. The success of these attempts is evaluated in the present section, revisiting each of the posed questions.

Question 1: Does emotion affect attentional control? The evidence collected in the present thesis consistently shows that reactions to incongruent situations that require executive control of attention are facilitated when they are made to emotional stimuli. Such an influence of emotional stimuli may be based on the fundamental role that fast discovering of, and rapid responding to emotionally salient cues play in evolutionary adaptation (LeDoux, 1995).

These data clarify the puzzling results of previous investigations that examined an influence of emotion on executive attentional control. Chapter 2 described these studies in greater detail. The main results were reduced Stroop conflict following positive, but not negative emotional words on the first of two subsequent Stroop stimuli (Kuhl & Kazén, 1999; Kazén & Kuhl, 2005). Alternatively, Dennis et al. reported effects of negative fearful, but not positive emotional faces on subsequent flanker conflict in some of their experiments; which, however, also depended on individual anxiety levels (Dennis et al., 2007; Dennis & Chen, 2007a, 2007b). The experimental designs applied in the present experiments yielded consistent effects showing enhanced attentional control for both, positive and negative emotional stimuli. A critical feature of the present experiments may have been that participants were required to make their responses to emotional stimuli, whereas the previous experiments presented unrelated accessory emotional stimuli that were detached from the task. Similarly to the interactions of emotion with other attentional functions showing that attention is oriented faster to an emotional stimulus, or that emotional stimuli increase alertness (see Section 3.4, e.g., Stormark et al., 1995), attentional control seems to be enhanced in reactions to emotional stimuli.

The next two paragraphs discuss two, more speculative, trains of thought regarding an emotion - executive attention interaction. Norman and Shallice (1986) suggested that attentional control is triggered in, among others, dangerous situations. Does that support the following reasoning? They defined attentional control (or supervisory attention, as they termed it) as the mechanism that comes into play when behavior can not be controlled by automatically triggered schemata for well-learned routine actions, e.g., when conflicting response tendencies are activated. Thus, it enables a decoupling of more rigid stimulus-response mappings. They suggest that dangerous situations may trigger this mechanism. If that is the case, then, if reaction to a stimulus requires attentional control (an incongruent stimulus), and that stimulus is a signal of danger (an emotional stimulus), this reaction should be facilitated. Such an interpretation of Norman and Shallice (1986) suggestion would explain the present data pattern perfectly well.

Scherer (1984, 1994) made a slightly different proposal. He argued that emotions are one (other?) mechanism to decouple stimulus and response. Thus, he does not specifically claim that emotion triggers attentional control, but that emotion provides the means to rapidly act in situations requiring a response beyond routine actions. Emotion constantly and rapidly evaluates "incoming information on the basis of a situationally weighted assessment of an event's relevance to central needs or goals and prepares appropriate adaptive action" (p. 127, Scherer, 1994). If the situationally weighted assessment of stimuli regarding a person's goals includes the presently activated individual intentions, then resolution of conflict with other competing activations should be facilitated. In this sense, emotion provides the means to rapidly exert attentional control in reactions to certain (emotionally salient) stimuli but not others. Thus, the phrasing of “triggered” executive attention would not exactly describe the proposed function, but the behavioral outcome of enhanced attentional control in emotional stimuli would be the same and would predict the data pattern found in the present experiments. It would also explain the difference between the present experiments and the earlier studies. As discussed above, in those experiments the emotional stimulus was not the one that participants reacted to. However, following the logic described here, it is in reaction to emotional stimuli that executive attentional control may be enhanced.

To summarize, the experiments presented in this thesis allow the conclusion that emotion can help determining the goal-coherent response in situations of conflict.

Question 2: What about positive emotion? One behavioral and two ERP studies demonstrated enhanced efficiency of executive attentional control in reactions to positive emotional stimuli. These results underscore the salience of positive emotional stimuli. As for negative emotional stimuli, fast detection of, and reaction to positive, reward-predicting, signals in the environment is highly evolutionarily adaptive. This function of positive emotion is less explored than that of negative emotional signals (Ohman, 2005; LeDoux, 2007). However, the present results, showing a strong attentional impact of positive emotional stimuli, are in line with other recent evidence. Brosch, Sander, et al. (2008) discussed that it is not exclusively fear, or negative valence, that modulate attention. Instead, they show that it is the relevance of a stimulus regarding the needs and goals of an individual, that determine its influence on attention. This was true for positive and negative emotional stimuli alike. Such effects can also nicely be shown when the relevance of a positive emotional stimulus is experimentally enhanced. Fasting individuals, e.g., exhibit an attentional bias towards food-related words (Leland & Pineda, 2006). The dramatic consequences of pathologically altered relevance attribution in positive emotional stimuli are apparent in patients with addictions (Koob, 2006). Striking effects of emotionally positive stimuli have also been reported in studies examining the neural basis of processing these stimuli, e.g., regarding the amygdala. Despite the dominant notion of the amygdala as a “fear module” (Ohman & Mineka, 2001; LeDoux, 2007), a recent meta-analysis of amygdala activations revealed stronger effect sizes for positive compared to negative emotional stimuli (Sergerie et al., 2008). In summary, the present dissertation avoided the one-sided view of some earlier reports on emotion by including positive and negative emotional stimuli. The similarity of the effects adds to recent evidence demonstrating the relevance of positive emotion.

Question 3: Emotion in words? Chapter 3 extensively discusses the specifics of verbal emotional stimuli. Even though the majority of past studies investigated emotional effects via face stimuli (in which mainly the eyes seem to be important, see Morris et al., 2002), the present experiments convincingly demonstrated that words are salient emotional stimuli as well. They may be argued to be of very low "biological preparedness" but have striking effects even early on during stimulus processing. The very earliest indices of emotion detection from visually presented words come from patients with intracranial electrodes in the amygdala (Landis, 2006). However, there is also EEG and MEG evidence that shows differences between emotional and neutral stimuli, already on the P1 amplitude (Li et al., 2007, 2008; Scott et al., 2008). What the exact mechanisms of this early emotion detection in words are, remains open (for a speculation see Chapter 3). Nevertheless, if emotion is detected, it may modulate subsequent information processing. This is what the experiments in the present dissertation could show. The speed of this modulatory action suggests that emotion detection from words was rapid too, leading over to the next question.

Question 4: Temporal dynamics? The question when the earliest indication of modulated executive attentional processes in emotion would be present was targeted with EEG. The most prominent ERP correlate of conflict processing is the N200 that may vary in timing, but is usually reported about 200 ms poststimulus onset (Veen & Carter, 2002b). Experiments 1 and 2 clearly showed that an interaction of emotion and conflict was already present on the N200 potential, which did start 190 ms after onset of the visual stimuli. For the auditory stimuli the story is a bit more complex. Here, the conflict N200 onset was not before 420 ms into presentation of the stimuli. As discussed above, this does not necessarily mean that Simon-type conflict is detected later in general, only in the present design, the gender of the voice had to be identified first, before conflict was present. To exactly determine the point in time at which the voice gender was recognized and consequently conflict could be detected, a gating experiment would be required. However, the delay in the behavioral responses of approximately the same amount as the delay in the N200 onset suggest that the N200 may have occurred around the same time after conflict detection as in the visual design. Modulation of conflict processing in emotion at this point in time also resembled the data from the visual ERP experiments. In conclusion, the influence of emotion on executive attention is already present in the earliest index of conflict processing around 200 ms.

Question 5: Correlates in the brain? The involvement of the dorsal ACC in processing conflict is in line with a large body of previous research observing activations in different types of conflict tasks (for a recent meta-analysis see Nee et al., 2007). Of interest for the present dissertation are also the activations for emotional words in the amygdala. The crucial role of the amygdala in emotion is undisputed. There is also accumulating evidence demonstrating its involvement in the processing of emotional words (for the first fMRI publication on positive and negative words see Hamann & Mao, 2002), which is, however, confronted with some studies failing to find such activations (e.g., Kuchinke et al., 2006). The amygdala projects (among other regions) to the ventral division of the ACC, which has been found to be active in a variety of tasks involving emotional stimuli. Very recently, Etkin et al. (2006) found activation in this region for resolution of emotional conflict. It was therefore hypothesized that the ventral ACC may be sensitive to conflict under certain conditions, namely when target stimuli are emotional. This is what the two fMRI studies revealed. The ventral ACC seems to integrate emotional relevance information with the current goals set in a task, yielding activation when reaction to an emotional stimulus requires attentional control because of present goal-conflicting activations. As Allman et al. (2001) suggested, the ACC may really fulfill the function of an “interface between emotion and cognition“(p. 107) to generate evolutionary adaptive behavior. Is this integrative function one that is especially vital in humans, as the occurrence of specialized neurons (von Economo neurons) in the ACC in almost exclusively humans suggests (see Section 3.4.3)? This question is of course unanswerable at the moment, others, however, may not be.

Why is the ventral ACC activation in the auditory experiment lateralized to the right hemisphere? It was already alluded to the possibility that the reason could lie in the present emotional prosody which has been found to activate mainly right-hemispheric regions (for a review see Schirmer & Kotz, 2006). Another option is that the right lateralization is due to the negative valence of the stimuli. Such an interpretation would be in line with the suggestion of Davidson (2003) for a right hemisphere negative emotion, and a left hemisphere positive emotion system. However, the visual fMRI experiment in which no hemispheric differences were found also used negative emotional stimuli. The question could be addressed by future research (see below).

For the present dissertation, the division of the ACC in a dorsal and a ventral portion as suggested by Bush et al. (2000) was adapted. However, examination of the ventral ACC activation foci shows that they all fall in the subgenual part of the ventral ACC (see Figure 9.1). Considering the variability of the exact locations of conflict activations in the ACC across different studies and conflict tasks, it is astonishing how closely the present ventral ACC activations lie together. Replication of this result may eventually allow more finegrained functional parcellation of the ventral ACC, e.g., differentiation of pre- and subgenual functions.

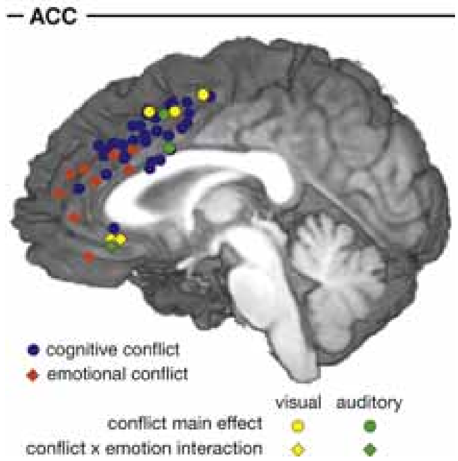

Figure 9.1: Peak activations from cognitive and emotional conflict studies listed in Table 2.1. Activation foci from the present experiments are displayed in yellow for the visual flanker, and in green for the auditory Simon task. The dorsal ACC was activated by incongruent vs. congruent stimuli (conflict main effect). The ventral ACC showed conflict activation in emotional stimuli only (conflict x emotion interaction).

Question 6: Generalizable? The present thesis tested its major question of an emotional influence on executive attention in several different experiments, with negative and positive stimuli in the EEG, and negative stimuli in the fMRI. This set of experiments was repeated with a different conflict paradigm, in a different sensory modality. It may seem a bit repetitive, but replication of effects in different experimental settings allows some conclusions about reliability and generalizability of these effects. The results of all of the experiments reported here point in the same direction, attentional control is enhanced in responses to emotional stimuli. Thus, to provide a quick answer to question 6, the effects seem to be generalizable! However, the question could of course be tested even more vigorously, e.g., with different measures of attentional control (for ideas see Chapter 10).

Question 7: An effect in audition? Two different types of emotional stimuli were used in the present experiments, visually presented words, and auditorily presented spoken words. In general, the effects on executive attention are very similar which suggests that both, reading and hearing of emotional words enhances attentional control in reactions to those words. The major differences between the visual and auditory experiments were already discussed above. To quickly summarize, longer latencies of responses and of the conflict N200 is most likely due to later detection of conflict the auditory stimuli, as the gender of the voices had to be identified first. The right lateralization of the ventral ACC activity may be caused by the emotional prosodic cues in the auditory stimuli.

Question 8: What about interindividual differences? Interindividual differences in temperamental effortful control, anxiety, and depression were consistently associated with the experimental effects. Especially in reaction to negative emotional stimuli, participants low in effortful control, and high in anxiety and depression showed a reduced enhancement in attentional control. Also the conflict N200 enhancement was reduced, as was the activation in the ventral ACC. These studies are in line with previous work in subclinical and clinical depression and anxiety which showed deficient processing of negative emotional stimuli. Among other indices, this was shown by hyperactivation in the amygdala and lack of ACC activity (Drevets et al., 1997; Siegle et al., 2007). The specificity of the observed correlations is demonstrated by the lack of an association of the individual stress level with any of the measures. However, the question whether the effects of anxiety and depression can be differentiated should be addressed in future research (see Chapter 10). Even though the correlational pattern was replicated in each of the experiments with negative emotional stimuli (in some cases producing only marginal significance), the correlations must be critically evaluated as they stem from rather small samples and no correction for multiple comparisons was applied. The latter, however, is based on several arguments discussed by Perneger (1998), the main reason being that the whole pattern of correlations between the questionnaire and the RT, ERP, and fMRI data was of interest. Thus, a 5% threshold should be applied to this ”global“ test and not to each single correlation (for the common practice of this see, e.g., Bishop et al., 2004; Bishop, 2007; Haas et al., 2007; Hensch, Herold, & Brocke, 2007).

Chapter 10

Perspectives

The present chapter discusses potential caveats and drawbacks of the experiments in Section 10.1. Section 10.2 presents a conglomerate of potentially interesting experimental ideas that could follow up on the experiments described in this thesis.

10.1 Critique

A critical point regarding the visual flanker design (Chapter 7) may arise from investigations of the "emotional Stroop" phenomenon stating that color naming latencies of emotional words are prolonged compared to neutral words, as emotional stimuli create some conflict-like interference (for a discussion of the task see Chapter 3, Ray, 1979; Williams et al., 1996). This should have affected RTs in the emotional trials; however, such a main effect of emotionality was not observed. Also, the emotional Stroop task has been criticized as (1) there is no conflict between competing response tendencies (Algom et al., 2004), (2) an effect is only present in blocked designs (Compton, 2003; Chajut et al., 2005), (3) effects have been mainly restricted to clinical populations and are not present in healthy controls (Williams et al., 1996) or habituate rapidly (Compton, 2003), and (4) Larsen et al. (2006) showed in a review that response slowing in the emotional Stroop task may be due to the emotional words used being lower in frequency of usage, longer in length, and having smaller orthographic neighborhood. It is therefore unlikely that the emotional Stroop phenomenon confounded results in the visual experiments. Furthermore, would the logic of the emotional Stroop task not require any response to one of the non-emotional features (like ink color) to be prolonged? Thus, the voice gender decision task applied in the auditory experiments also presents a counterexample, as no delayed responses for emotional stimuli were found either.

Another issue concerns the emotional salience of the used material. The valence and arousal ratings of the visual and auditory words were taken to infer their “emotionality”. Even though this is a widely applied and accepted procedure, it is not optimal. The emotional salience of each particular item may vary from individual to individual, it would therefore be advantageous to have ratings of the stimuli by each participant of each experiment. This should be done after the main experiment to avoid repetition effects in the results of the experiment; however, these are then present in the ratings. Additionally to the subjective ratings, it would also be helpful to have other objective measures of the emotional salience of items. In the present dissertation this was achieved by testing the attentional effect of the selected emotional words that had been described before (see Section 7.3). However, there are also other measures that would be useful, like peripheral physiological indices including skin conductance, or pupillary dilatation. Combining subjective and objective measures may allow optimal determination of the emotional salience of specific stimuli.

Another possible critique concerns the matching of word meaning with the prosodic manipulation. This point only applies to the groups of positive and negative emotional words. Emotionally neutral words were always spoken in neutral prosody. For the emotional groups, however, prosodically coherent negative and positive stimuli were created by having the negative words read in angry, the positive words in happy prosody. Thus, for the sake of variance reduction, potential mild mismatches were accepted. These mismatches might have occurred for a few words like “sadness” or “breakup” for which the better matching prosodic manipulation would obviously have been sad, not angry prosody. This issue was not explicitly investigated in the present thesis; however, none of the participants reported notice of these mismatches, and they did not affect the ratings of the auditory stimuli (see Section 8.2). Also, if this mismatch did have an effect, then it should not facilitate processing of the concerned stimuli, but rather slow it. That means, if having an effect, mismatch would bias RTs in the opposite direction than what the actual results showed.

Each of the experiments described in this dissertation yielded a significant main effect of conflict in the RTs and the N200 potential over anterior electrodes. In emotional trials, the RT conflict was reduced while the N200 was enlarged in each experiment. In contrast, when comparing the conflict main effects to the conflict effects in neutral trials, RT conflict was increased and the N200 potential was decreased. Neither the RT conflict effect, nor the conflict N200 were eliminated in any of the cases; however, the reduction was in some of the experiments strong enough to render the remaining effect non-significant (this was the case in Experiment 2, where the RT conflict effect was not significant in positive emotional trials). Kuhl and Kazén (1999) interpreted such a reduced Stroop effect in the first of two Stroop stimuli after presentation of positive words as "removal of Stroop interference" (p. 382). However, a small numerical difference had still been present and might even be statistically significant in larger samples. This is of course speculation, but the consistent presence of a numerical conflict effect in all conditions over all experiments reported here suggests that the conflict effect was not removed (in Experiment 2), but reduced. The same argumentation applies to the N200 effects.

10.2 Open questions and future directions

As described above, Experiment 6 with auditory emotional stimuli largely replicated the critical activation foci in the ACC and the amygdala that had been observed in Experiment 3 with visual emotional stimuli. The main difference lay in the lateralization of the ventral ACC activation to the right hemisphere only in the auditory experiment. Other studies using auditory verbal stimuli with emotional prosody also reported a general right hemisphere dominance (for reviews on emotional prosody see Kotz et al., 2006; Schirmer & Kotz, 2006). It is, thus, likely that the emotional prosodic cues in the stimuli used in the present experiments caused this right-hemispheric shift in activation. However, to disentangle the effects of emotional word meaning and emotional prosody, potentially clarifying the lateralization differences, the use of other material may be helpful. Pseudowords, e.g., are phonotactically legal nonwords, which are deprived of any meaning. These stimuli could be applied to investigate the isolated impact of emotional prosody.

One obvious open question is whether the effect of positive emotional stimuli on conflict processing are subserved by the same brain regions as those found for negative stimuli. The relative similarity in the EEG scalp distributions of the effects may suggest involvement of similar brain regions; however, as discussed in Chapter 1, the EEG does not allow direct inferences about the neural generators of effects, especially when deeper brain regions are concerned. The best way to answer the question would therefore be to repeat the experiments with positive emotional stimuli in fMRI. Such a study could also help elucidating the alternative explanation to that discussed in the previous paragraph, for the hemispheric differences in the ventral ACC activation in Experiment 6. If these were due to the emotional stimuli used being of negative valence, as suggested by a model of emotional lateralization (see Chapter 9 Davidson, 2003), then the hemispheric differences should be reversed when using positive emotional stimuli.

The reason for a lack of an effect in the error rates is most probably the generally very high accuracy of performance. It would, therefore, be interesting to see if enhancing task difficulty (e.g., through accelerated presentation rate) would also yield effects on the error rates. Would the reduced RTs in incongruent emotional stimuli be accompanied by reduced error rates, or would they come at the cost of decreased accuracy? The interpretation of the effects offered in the previous chapter seems to favor the former; however, it is an empirical question that remains to be answered.

The present dissertation tested the generalizability of the observed influence of emotion on executive attention by applying different forms of conflict (target and flanker incongruency versus stimulus response incompatibility), and presenting stimuli in different sensory modalities (visual and auditory). Nevertheless, this point could be pushed even further. It was already alluded to the possibility of testing "pure" emotional prosody. Other emotional stimuli such as faces or pictures, dynamic visual or audiovisual stimuli could be applied as well. An interesting option would also be to present target stimuli that are directly motivationally relevant in that they relate behavioral performance to certain positive or negative consequences (Seifert et al., 2006). Similarly, generalizability may be tested with, not only different forms of conflict, but also other situations requiring executive attentional control, e.g., switching task sets (it may, however, be difficult, to incorporate emotional stimuli, for an example see Dreisbach & Goschke, 2004).

Comparison of the Simon and flanker ERP studies in the present thesis reveals consistent timing differences. As discussed above (see, e.g., Chapter 9), it is hard to exactly interpret these timing differences because of the complexity of the presented auditory stimuli. Nevertheless, the question remains if flanker-target incongruency and stimulus-response incompatibility processing follows the same time-course. There is little evidence that could help to answer this question (previous Simon EEG studies often applied a mixture of stimulus-response and other conflict, e.g., Carriero et al., 2007). To the authors knowledge there is no study yet that directly compared the Simon and flanker tasks in the EEG (for fMRI evidence see Chapter 2). Such an investigation would provide valuable information for further examination of interactions between conflict and other processes.

The experiments in the present dissertation also investigated the neural basis of an emotional influence on executive attention. Future studies could build on this evidence and apply other neuroscientific tools to further specify the neural basis. It would be very interesting to further explore the observed N200 component. Could source localization of this conflict N200 in emotional and neutral trials provide evidence that conforms the fMRI results? The better spatial resolution of magnetoencephalography could also help elucidating this question. Given the existing fMRI data it would even be possible to do fMRI constrained source localization. There are also tools to gain insight into the functional relation of the observed fMRI activation foci such as psychophysical interaction analysis or structural equation modeling. These methods could substantiate the functional interpretation of the network of activations observed.

The correlations of subclinical anxiety and depression with a reduced enhancement of attentional control in reactions to negative emotional stimuli suggest application of the paradigm to patient populations. This could (1) validate the correlational pattern which is currently based on relatively small subclinical variations in anxiety and depression. (2) Patient data may also help to differentiate the impact of depression and anxiety. In the student samples of the presented experiments, anxiety and depression had almost identical effects, which may be due to the factors being intercorrelated.[1] (3) The design developed for the present experiments may prove useful to investigate deficient emotional processing in patient groups. Clearly, further validation of the paradigm would be required before such an application could be considered. (4) Effortful control showed the opposite relation to the influence of emotion on executive attention than depression and anxiety. As effortful control describes the ability to regulate attentional processes and is associated with emotion regulation, this may indicate that individuals high in depression or anxiety could benefit from training of these abilities.

10.3 Final remarks

The present dissertation set out to explore a largely ignored question, namely whether executive control of attention is enhanced in reaction to emotional stimuli. While previous work showed that emotional stimuli can orient spatial attention and increase alertness, it had been unresolved

[1]These intercorrelations were not reported as they were not of primary interest, but they amounted to .50 as reported in the DASS manual and above (Lovibond & Lovibond, 1995).

whether emotional stimuli also trigger attentional control. The experiments described here provide a surprisingly clear answer to this question. For both, negative and positive emotional stimuli, attentional control is enhanced. To rigorously probe these results, a different experimental design was applied, and stimulation was done in a different sensory modality. Despite these modifications, the data pattern was replicated. Further evidence comes from a modulation of the conflict N200 potential, which also shows that emotional modulation of executive attention is a rapid process. Converging evidence from two fMRI studies provides further insight into the neural correlates. The ventral ACC plays an important role in the integration of emotion and attentional control. It responds to conflict exclusively in emotional stimuli, while the dorsal ACC is sensitive to conflict in general. Furthermore, the amygdala responds to emotion regardless of conflict. This pattern of activation can help to clarify the role of the ACC and its subcomponents in attentional and emotional regulation.

Taken together, the experiments in this dissertation add an important aspect to our understanding of the "neural mechanisms of emotional attention" (p.585, Vuilleumier, 2005).

Part IV

Appendix

Appendix A

Questionnaires

A.1 Adult temperament questionnaire

Instructions and response options

English. On the following pages you will find a series of statements that individuals can use to describe themselves. There are no correct or incorrect responses. All people are unique and different, and it is these differences which we are trying to learn about. Please read each statement carefully and give your best estimate of how well it describes you.

German. Auf den folgenden Seiten stehen eine Reihe von Aussagen, mit denen sich Menschen beschreiben können. Es gibt keine richtigen oder falschen Antworten. Jeder Mensch ist einzigartig und unterscheidet sich von anderen und uns geht es mit diesem Fragebogen um genau diese Unterschiede. Bitte lesen Sie jede Aussage sorgfältig durch und schätzen Sie ein, wie gut sie Sie beschreibt.

1.	extremely untrue	trifft gar nicht zu
2.	quite untrue	trifft nicht zu
3.	slightly untrue	trifft kaum zu
4.	neither true nor false	weder wahr noch unwahr
5.	slightly true	trifft etwas zu
6.	quite true	trifft zu
7.	extremely true	trifft absolut zu
8.	not applicable	nicht anwendbar

Table A.1: Response options in the ATQ in English and in the German translation.

List of items

Inhibitory Control	
13.	If I want to, it is usually easy for me to keep a secret. Wenn ich will, kann ich ein Geheimnis leicht für mich behalten.
28.	It is easy for me to hold back my laughter in a situation when laughter wouldn't be appropriate. In Situationen in denen es unangebracht ist, fällt es mir leicht Lachen zurückzuhalten.
41R.	When I see an attractive item in a store, it's usually very hard for me to resist buying it. Wenn ich etwas Schönes in einem Geschäft sehe, fällt es mir meist sehr schwer es nicht zu kaufen.
55.	I can easily resist talking out of turn, even when I'm excited and want to express an idea. Es ist kein Problem für mich nicht zu reden wenn ich nicht an der Reihe bin, auch wenn ich sehr aufgeregt bin und eine Idee die ich habe erklären möchte.
64.	When I decide to quit a habitual behavioral pattern that I believe to be undesirable, I am usually successful.

continues on next page...

	Wenn ich mich dazu entscheide eine Gewohnheit abzulegen die ich unangenehm finde, kriege ich das meistens hin.
86R.	When I'm excited about something, it's usually hard for me to resist jumping right into it before I've considered the possible consequences. Wenn ich mich auf etwas freue, fällt es mir meist schwer nicht gleich anzufangen, bevor ich die möglichen Konsequenzen bedacht habe.
107.	Even when I feel energized, I can usually sit still without much trouble if it's necessary. Selbst wenn ich unter Strom stehe, fällt es mir nicht schwer still zu sitzen, wenn es nötig ist.
128R.	I often avoid taking care of responsibilities by indulging in pleasurable activities. Ich vermeide es oft mich meinen Pflichten zu widmen indem ich angenehmen Aktivitäten nachgehe.
140R.	At times, it seems the more I try to restrain a pleasurable impulse (e.g., eating candy), the more likely I am to act on it. Manchmal scheint es mir, dass, je mehr ich versuche einen angenehmen Impuls zu unterdrücken (z.B. Süßes zu essen), desto wahrscheinlicher ist es, dass ich es dennoch tue.
147R.	I usually have trouble resisting my cravings for food drink, etc. Ich habe meist Probleme meinem Verlangen nach Essen, Trinken, etc. zu widerstehen.
172.	It is easy for me to inhibit fun behavior that would be inappropriate. Es ist leicht für mich angenehme, aber unangemessene, Verhaltensweisen zu unterdrücken.
Activation Control	
32.	I usually finish doing things before they are actually due (e.g., paying bills, finishing homework, etc.). Meist habe ich die Dinge schon erledigt bevor sie fällig sind (z.B. Rechungen bezahlen, Hausaufgaben beenden, etc.).
50R.	I am often late for appointments. Ich komme oft zu spät zu Terminen.

continues on next page...

62R.	I often make plans that I do not follow through with. Ich mache oft Pläne die ich dann nicht einhalte.
84.	As soon as I have decided upon a difficult plan of action, I begin to carry it out. Sobald ich mich für einen schwierigen Plan entschieden habe, beginne ich diesen umzusetzen.
96.	If I think of something that needs to be done, I usually get right to work on it. Wenn ich an etwas denke, das noch erledigt werden muss, fange ich meist gleich damit an.
109.	I can make myself work on a difficult task even when I don't feel like trying. Ich kann mich selbst dazu motivieren an einer schwierigen Aufgabe zu arbeiten, auch wenn mir nicht danach ist es zu probieren.
117R.	Even when I have enough time to complete an activity today, I often tell myself that I will do it tomorrow. Auch wenn ich genug Zeit habe eine Sache heute zu erledigen, sage ich mir oft, dass ich es morgen machen werde.
138R.	If I notice I need to clean or wash something (e.g., car, apartment, laundry, etc.), I often put it off until tomorrow. Wenn ich merke, dass etwas geputzt oder gewaschen werden muss (z.B. Auto, Wohnung, Wäsche, etc.), verschiebe ich es oft auf morgen.
149R.	I hardly ever finish things on time Ich kriege Dinge fast nie rechtzeitig fertig.
153.	I usually get my responsibilities taken care of as soon as possible. Ich kümmere mich gewöhnlich so schnell wie möglich um meine Aufgaben.
156R.	When I am afraid of how a situation might turn out, I usually avoid dealing with it. Wenn ich Angst vor dem Ausgang einer Situation habe, vermeide ich es oft mich damit auseinanderzusetzen.
177.	I can keep performing a task even when I would rather not do it. Es fällt mir leicht eine Sache fortzuführen, auch wenn ich keine Lust dazu habe.
Attentional Control	

continues on next page...

Attentional Shifting from Punishment	
43R.	When I am sad about something, it is hard for me to keep my attention focused on a task. Wenn ich traurig bin fällt es mir schwer, mich auf eine Aufgabe zu konzentrieren.
71R.	When I am anxious about the outcome of something, I have a hard time keeping my attention focused on a task. Wenn ich mir Sorgen darüber mache wie eine Sache ausgehen könnte, kann ich mich nur schwer auf eine Aufgabe konzentrieren.
112R.	It is very hard for me to focus my attention when I am distressed. Es fällt mir sehr schwer mich zu konzentrieren, wenn es mir schlecht geht.
Attentional Shifting from Reward	
15R.	When I am happy and excited about an upcoming event, I have a hard time focusing my attention on tasks that require concentration. Wenn ich mich sehr auf etwas Bevorstehendes freue, fällt es mir schwer meine Aufmerksamkeit auf eine komplizierte Aufgabe zu lenken.
89R.	When I am especially happy, I sometimes have a hard time concentrating on tasks that require me to keep track of several things at once. Wenn ich sehr glücklich bin fällt es mir manchmal schwer mich auf eine Aufgabe zu konzentrieren, bei der ich mich auf mehrere Dinge zugleich konzentrieren muss.
131R.	When I hear good news, my ability to concentrate on taking care of my responsibilities goes out the window. Wenn es gute Neuigkeiten gibt, macht sich meine Fähigkeit mich um meine Pflichten zu kümmern, aus dem Staub.
Attentional Focusing	
6R.	When I am trying to focus my attention, I am easily distracted. Ich lasse mich leicht ablenken, wenn ich mich auf etwas konzentrieren will.
24R.	When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.

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	Es fällt mir schwer ablenkende Gedanken zu unterdrücken, wenn ich mich konzentrieren will.
53R.	When trying to study something, I have difficulty tuning out background noise and concentrating.
	Wenn ich lerne, fällt es mir schwer, Hintergrundgeräusche zu ignorieren und mich zu konzentrieren.
Attentional Shifting	
35.	When interrupted or distracted, I usually can easily shift my attention back to whatever I was doing before.
	Wenn ich unterbrochen oder abgelenkt werde, kann ich mich meist wieder schnell auf das konzentrieren was ich vorher gemacht habe.
68.	I am usually pretty good at keeping track of several things that are happening around me.
	Es fällt mir gewöhnlich leicht die Übersicht über mehrere Dinge gleichzeitig zu behalten.
175R.	It is often hard for me to alternate between two different tasks.
	Es fällt mir schwer zwischen zwei verschiedenen Aufgaben hin und her zu wechseln.

Table A.2: Effortful control items of the adult temperament questionnaire in the English original and in the German translation. Numbers indicate the position of each item in the ATQ. Items with an R are the conceptual reverse of the scale definition and were reverse coded.

A.2 Depression anxiety stress scales

Instruction and response options

English. Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

German. Bitte lesen Sie jede Aussage und kreisen Sie die Zahl 0, 1, 2 oder 3 ein, die angeben soll, wie sehr die Aussage während der letzten Woche auf Sie zutraf. Es gibt keine richtigen oder falschen Antworten. Versuchen Sie, sich spontan für eine Antwort zu entscheiden.

0	Did not apply to me at all	Traf gar nicht auf mich zu
1	Applied to me to some degree, or some of the time	Traf manchmal auf mich zu, oder zu einem gewissen Grad
2	Applied to me to a considerable degree, or a good part of time	Traf in beträchtlichem Maße auf mich zu, oder ziemlich oft
3	Applied to me very much, or most of the time	Traf sehr stark auf mich zu, oder die meiste Zeit

Table A.3: Response options in the DASS in English and in the German translation.

List of items

Depression	
3	I couldn’t seem to experience any positive feeling at all Ich konnte überhaupt keine positiven Gefühle erleben
5	I just couldn’t seem to get going Ich konnte einfach nicht in Gang kommen
10	I felt that I had nothing to look forward to Ich hatte das Gefühl, nichts zu haben, auf das ich mich freuen konnte
13	I felt sad and depressed

continues on next page...

	Ich fühlte mich traurig und niedergedrückt
16	I felt that I had lost interest in just about everything
	Ich fühlte, daß ich das Interesse an allem verloren hatte
17	I felt I wasn't worth much as a person
	Ich fühlte mich als Person nicht viel wert
21	I felt that life wasn't worthwhile
	Ich hatte das Gefühl, daß das Leben sich nicht lohnt
24	I couldn't seem to get any enjoyment out of the things I did
	Es schien, als könnte ich die Dinge, die ich tat, überhaupt nicht genießen
26	I felt down-hearted and blue
	Ich fühlte mich niedergeschlagen und traurig
31	I was unable to become enthusiastic about anything
	Ich war nicht in der Lage, mich für irgendetwas zu begeistern
34	I felt I was pretty worthless
	Ich fühlte mich ziemlich wertlos
37	I could see nothing in the future to be hopeful about
	Ich konnte nicht hoffnungsvoll in die Zukunft blicken
38	I felt that life was meaningless
	Ich empfand das Leben als sinnlos
42	I found it difficult to work up the initiative to do things
	Es fiel mir schwer, die Initiative aufzubringen, Dinge zu tun
Anxiety	
2	I was aware of dryness of my mouth
	Ich spürte, daß mein Mund trocken war
4	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)
	Ich hatte Atemprobleme (z.B. übermäßig schnelles Atmen, Atemlosigkeit ohne körperliche Anstrengung)
7	I had a feeling of shakiness (eg, legs going to give way)

continues on next page...

	Ich fühlte mich zittrig (z.B. schwach in den Beinen)
9	I found myself in situations that made me so anxious I was most relieved when they ended
	Ich fand mich in Situationen wieder, die mich so ängstlich machten, daß ich sehr froh war, wenn sie vorbei waren
15	I had a feeling of faintness
	Ich hatte das Gefühl, ohnmächtig zu werden
19	I perspired noticeably (eg, hands sweaty) in the absence of high temperatures or physical exertion
	Ich schwitzte spürbar (z.B. feuchte Hände), ohne daß hohe Temperaturen herrschten oder daß ich mich körperlich anstrengte
20	I felt scared without any good reason
	Ich fühlte mich grundlos ängstlich
23	I had difficulty in swallowing
	Ich hatte Schluckbeschwerden
25	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)
	Ich war mir über meinen Herzschlag bewußt, ohne daß ich mich körperlich angestrengt hatte (z.B. das Gefühl beschleunigten Herzschlags, das Gefühl, daß der Herzschlag aussetzt)
28	I felt I was close to panic
	Ich fühlte mich einer Panik nahe
30	I feared that I would be "thrown" by some trivial but unfamiliar task
	Ich befürchtete, daß mich eine einfache, aber ungewohnte Aufgabe aus der Bahn werfen würde
36	I felt terrified
	Ich fühlte mich erschrocken
40	I was worried about situations in which I might panic and make a fool of myself

continues on next page...

	Ich machte mir Sorgen über Situationen, in denen ich in Panik geraten und mich zum Trottel machen könnte
41	I experienced trembling (eg, in the hands)
	Ich zitterte (z.B. an den Händen)
Stress	
1	I found myself getting upset by quite trivial things
	Ich bemerkte, daß ich mich über Kleinigkeiten aufregte
6	I tended to over-react to situations
	Ich tendierte dazu, auf Situationen überzureagieren
8	I found it difficult to relax
	Ich fand es schwierig, mich zu entspannen
11	I found myself getting upset rather easily
	Ich bemerkte, daß ich mich ziemlich schnell aufregte
12	I felt that I was using a lot of nervous energy
	Ich fühlte, daß ich eine Menge Nervenkraft verbrauchte
14	I found myself getting impatient when I was delayed in any way (eg, lifts, traffic lights, being kept waiting)
	Ich bemerkte, daß ich ungeduldig wurde, wenn ich irgendwie aufgehalten wurde (z.B. im Fahrstuhl, an Ampeln, wenn man mich warten ließ)
18	I felt that I was rather touchy
	Ich fand mich ziemlich empfindlich
22	I found it hard to wind down
	Ich fand es schwer, mich zu beruhigen
27	I found that I was very irritable
	Ich stellte fest, daß ich sehr reizbar war
29	I found it hard to calm down after something upset me
	Ich fand es schwer, mich zu beruhigen, wenn mich etwas geärgert hatte
32	I found it difficult to tolerate interruptions to what I was doing
	Ich fand es schwierig zu tolerieren, wenn ich bei einer Tätigkeit unterbrochen wurde

continues on next page...

33	I was in a state of nervous tension
	Ich war in einem Zustand nervöser Anspannung
35	I was intolerant of anything that kept me from getting on with what I was doing
	Ich konnte nichts ertragen, das mich davon abhielt, in meiner Tätigkeit fortzufahren
39	I found myself getting agitated
	Ich bemerkte, daß ich unruhig wurde

Table A.4: Depression, anxiety, and stress items of DASS in the English original and in the German translation. Numbers indicate the position of each item in the questionnaire.

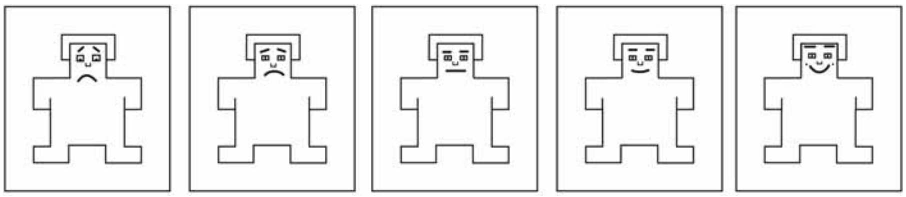
Appendix B

Experimental instructions

B.1 Ratings

Valence rating: English instruction

In this experiment you will see different words. Your task is to evaluate whether the words are pleasant, neutral, or unpleasant for you. We are interested in your first impression, it is therefore important that you push a button as soon as possible.



The sad manikin stands for **negative unpleasant feelings** about a word, e.g., idiot.	The manikin with the straight mouth stands for the **neutral words**, e.g., antenna.	The smiling manikin stands for **positive pleasant feelings** about a word, e.g., vacation.

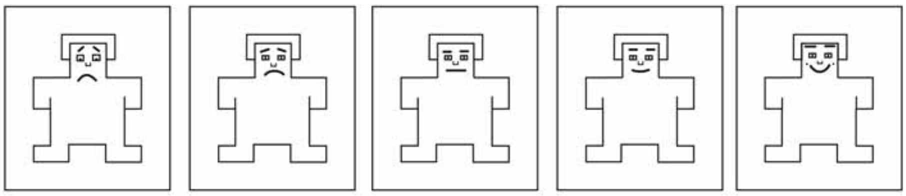
Please give your response on the nine yellow buttons on the keyboard.

There are ten experimental blocks with 100 words each.

HAVE FUN!

Valence rating: German instruction

Bei diesem Experiment wirst Du verschiedene Wörter sehen. Du sollst jedes Wort dahingehend einschätzen ob es für Dich eher angenehm, unangenehm oder neutral ist. Dabei geht es um Deinen allerersten Eindruck. Es ist also wichtig, dass Du so schnell wie möglich eine Taste drückst.



Das traurige Männchen steht für eher **negative unangenehme Gefühle** bei einem Wort, z.B. Idiot.	Das Männchen mit dem geraden Mund steht für die **neutralen Wörter**, z.B. Antenne.	Das lächelnde Männchen steht für eher **positive angenehme Gefühle** bei einem Wort, z.B. Ferien.

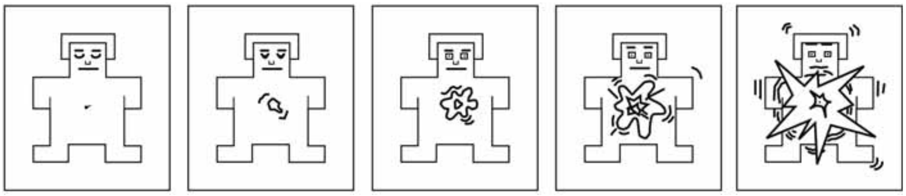
Bitte gib Deine Einschätzung auf den neun gelben Tasten der Tastatur.

Es gibt insgesamt zehn Blöcke mit jeweils 100 Wörtern.

VIEL SPASS!

Arousal rating: English instruction

In this experiment you will see different words. Your task is to evaluate whether the words are arousing or not arousing for you. We are interested in your first impression, it is therefore important that you push a button as soon as possible.



This manikin stands for **words that are not arousing**, e.g., motto or committee.	This manikin stands for **arousing words**, e.g., massacre, erection, nausea or massage.

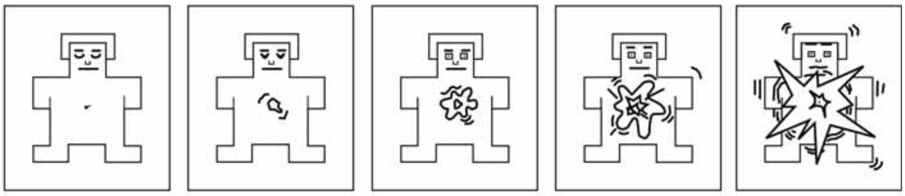
Please give your response on the nine yellow buttons on the keyboard.

There are ten experimental blocks with 100 words each.

HAVE FUN!

Arousal rating: German instruction

Bei diesem Experiment wirst Du verschiedene Wörter sehen. Du sollst jedes Wort dahingehend einschätzen wie erregend es für Dich ist. Dabei geht es um Deinen allerersten Eindruck. Es ist also wichtig, dass Du so schnell wie möglich eine Taste drückst.



Dieses Männchen steht für **Worte die nicht erregend** sind, z.B. Devise oder Gremium.	Dieses Männchen steht für **erregende Worte** wie z.B. Gemetzel, Erektion, Übelkeit oder Massage.

Bitte gib Deine Einschätzung auf den neun gelben Tasten der Tastatur.

Es gibt insgesamt zehn Blöcke mit jeweils 100 Wörtern.

VIEL SPASS!

Concreteness rating: English instruction

In this experiment you will see different words. Your task is to evaluate whether the words are more concrete or abstract for you. We are interested in your first impression, it is therefore important that you push a button as soon as possible.

Concrete are all those things that are in some way imageable, that you could draw or touch (e.g., floor), but also air for example as you can sense it.

Abstract are all those things are not imageable, for which you can not have a mental image, like emotions or concepts (e.g., thrill, psychology).

Please give your response on the nine yellow buttons on the keyboard. There are ten experimental blocks with 100 words each.

HAVE FUN!

Concreteness rating: German instruction

Bei diesem Experiment wirst Du verschiedene Wörter sehen. Du sollst jedes Wort dahingehend einschätzen ob es für Dich eher eher konkret oder abstrakt ist. Dabei geht es um Deinen allerersten Eindruck. Es ist also wichtig, dass Du so schnell wie möglich eine Taste drückst.

Konkret sind all jene Dinge, die irgendwie bildlich sind, die man zum Beispiel aufmalen oder anfassen könnte (Fußboden), aber auch z.B. Luft wäre konkret, man kann sie sinnlich fühlen.

Abstrakt sind all jene Dinge, die nicht bildlich sind, bei denen man keine bildliche Vorstellung hat, wie Emotionen, oder Konzepte (z.B. Nervenkitzel, Psychologie).

Bitte gib Deine Einschätzung auf den neun gelben Tasten der Tastatur. Es gibt insgesamt zehn Blöcke mit jeweils 100 Wörtern.

VIEL SPASS!

Auditory ratings

The auditory valence and arousal rating instructions were identical to those in the visual rating, only the first two sentences were replaced:

English instruction In this experiment you will hear different words. Your task is to evaluate whether the words are [...] for you. So please evaluate the way in which the words were spoken.

German instruction Bei diesem Experiment wirst Du verschiedene Wörter hören. Du sollst jedes Wort dahingehend einschätzen ob es für Dich [...] klingt, Du sollst also die Art wie das Wort ausgesprochen wurde einschätzen.

B.2 Visual paradigm

English instruction

Your task is to decide whether a word is printed in red

BRUSH

(printed in red)

or in green.

BRUSH

(printed in green)

Before the words appear, there will be a cross in the center of the screen which you are to fixate. Then there will be three words, one above the other, your task is to evaluate the printin ink of the central word, in these cases this would be red:

BRUSH **BRUSH** **BRUSH**	**BRUSH** **BRUSH** **BRUSH**

Please always respond as **fast** and **accurately** as possible!

German instruction

Bei dieser Aufgabe sollst Du immer entscheiden, ob ein Wort in roter Druckschrift

PINSEL

(in roter Farbe)

oder in grüner Schrift gedruckt ist.

PINSEL

(in grüner Farbe)

Bevor die Worte erscheinen wird in der Mitte des Bildschirms ein Kreuz zu sehen sein, auf dieses Kreuz sollst Du schauen. Es erscheinen dann immer drei Worte, die übereinander stehen, Du sollst immer nur die Farbe des in der Mitte stehenden Wortes beurteilen, z.B. wäre das in diesen Fällen rot:

PINSEL	**PINSEL**
PINSEL	**PINSEL**
PINSEL	**PINSEL**

Bitte antworte immer so **schnell** und **akkurat** wie möglich!

B.3 Auditory paradigm

English instruction

In this experiment you will hear words through the headphones, e.g., lift, flower pot, or cloud. These words are only presented to one ear, either to the right or left. Also, words will either be spoken by a man or a woman.

Your task is to decide if the speaker of the word is male or female. The presentation side of the word is not relevant.

In this experiment it is important that you respond as **fast**, but also as **accurately** as possible!

German instruction

In diesem Experiment wirst Du über Kopfhörer einzelne Wörter hören wie z.B. Fahrstuhl, Blumentopf oder Wolke. Diese Wörter werden immer nur auf einem Ohr zu hören sein, also entweder links oder rechts. Außerdem werden die Wörter manchmal von einem Mann und manchmal von einer Frau gesprochen.

Deine Aufgabe ist es zu entscheiden ob der Sprecher des eben gehörten Wortes männlich oder weiblich ist. Die Seite auf der das Wort zu hören ist, ist nicht von Bedeutung.

Es ist bei diesem Experiment besonders wichtig, dass Du so **schnell** wie möglich, aber auch so **akkurat** wie möglich antwortest!

Appendix C

List of Items

Word	Frequency	Letters	Syllables	Visual Valence	Visual Arousal	Visual Concreteness	Auditory Valence	Auditory Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
negative words - male speaker													
Aids*	11	4	1	2.03	7.22	6.52	7.38	7.17	0.61	72.68	269.86	299.17	208.54
Angst	8	5	1	2.16	6.97	7.81	7.57	7.17	0.62	72.64	271.93	309.36	219.14
Armut*	10	5	2	2.84	6.00	7.42	7.47	6.87	0.59	71.50	237.96	295.10	155.16
Bestie*	14	6	2	2.66	7.00	6.06	7.80	7.57	0.60	60.85	182.68	290.15	89.05
Biest*	15	5	1	2.94	6.88	5.29	8.13	7.50	0.88	70.75	227.37	313.41	77.01
Drogen*	10	6	2	2.22	7.06	3.19	6.30	7.10	0.72	74.42	257.66	311.99	183.36
Drohung	11	7	2	2.69	7.16	7.74	7.30	6.93	0.63	72.05	264.38	295.09	206.57
Elend	11	5	2	2.03	6.81	7.03	7.80	7.57	0.60	76.55	243.50	335.53	85.90
Feind*	10	5	1	2.28	7.13	6.27	8.00	7.66	0.76	73.42	280.20	324.27	200.87
Folter*	12	6	2	2.00	6.78	6.84	7.93	7.77	0.71	66.60	224.13	280.81	152.27
Furcht*	11	6	1	2.84	6.84	7.77	7.73	7.33	0.98	76.95	312.80	435.85	182.09
Geisel	13	6	2	2.13	7.03	4.43	7.87	7.77	0.57	65.01	250.82	324.69	167.89
Gewalt*	8	6	2	2.22	6.91	7.10	7.87	6.90	0.51	72.39	230.69	280.47	168.85
Grab	11	4	1	2.69	5.88	3.00	7.73	7.03	0.49	74.57	252.46	455.44	194.05
Hass*	12	4	1	2.28	7.66	7.81	7.90	7.67	0.55	76.51	295.78	300.65	286.82
Henker*	13	6	2	2.06	6.94	4.13	7.70	7.43	0.74	67.60	326.91	505.86	199.78
Hölle*	11	5	2	2.03	6.94	6.74	7.87	7.27	0.42	76.55	300.41	342.10	235.21
Krieg*	8	5	1	1.66	7.31	6.45	8.07	7.77	0.52	72.19	303.48	346.76	232.14
Krise	9	5	2	2.78	5.94	7.35	8.03	7.77	0.62	69.27	283.73	331.17	160.27
Leiche*	10	6	2	2.13	7.44	3.03	7.77	7.30	0.66	68.99	252.22	311.73	146.40
Lüge	11	4	2	2.94	7.06	7.50	7.80	7.48	0.83	63.08	196.33	310.95	101.50
Lügner*	13	6	2	2.78	7.06	6.74	7.93	7.87	0.90	65.75	249.02	356.57	131.15
Mord*	10	4	1	1.56	7.56	5.94	7.83	7.50	0.54	76.01	258.76	399.20	180.79
Mörder*	10	6	2	1.94	6.69	5.48	7.86	7.33	0.57	73.55	244.21	287.01	185.30
Opfer*	8	5	2	2.10	6.19	5.32	7.33	7.03	0.53	63.50	240.26	467.40	120.88
Räuber	11	6	2	2.94	5.72	3.77	7.57	7.13	0.61	71.13	248.30	329.87	137.27
Satan*	13	5	2	2.75	7.03	6.45	8.07	7.83	0.86	63.30	173.78	235.94	131.59
Schlampe*	16	8	2	2.75	7.06	5.29	7.77	7.47	0.73	67.51	167.63	277.09	125.18
Schmerz	11	7	1	2.94	6.56	7.45	7.67	8.03	0.84	73.85	432.99	496.70	337.24
Seuche	13	6	2	2.38	7.06	6.71	7.80	7.57	0.65	67.77	229.64	314.25	135.37

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				Visual			Auditory						
Word	Frequency	Letters	Syllables	Valence	Arousal	Concreteness	Valence	Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Streit*	8	6	1	2.25	5.63	6.87	7.77	7.80	0.93	74.25	287.14	334.74	207.43
Terror*	10	6	2	1.84	7.22	7.52	7.90	7.63	0.74	65.34	210.55	297.88	153.06
Teufel*	10	6	2	2.94	6.69	6.16	7.97	7.50	0.59	63.70	229.62	297.72	134.03
Tod*	8	3	1	1.91	7.22	6.94	7.87	7.10	0.45	75.07	369.21	547.10	233.40
Trauer*	11	6	2	2.59	6.84	7.81	7.40	7.13	0.59	68.47	267.80	484.67	153.20
Trauma*	13	6	2	2.78	6.94	7.13	7.77	7.31	0.84	69.30	235.84	289.57	75.72
Trennung*	10	8	2	2.88	7.25	6.65	7.77	7.33	0.55	69.71	250.52	304.13	87.96
Tumor*	13	5	2	2.19	6.78	3.65	7.62	7.45	0.59	64.83	205.32	321.29	117.52
Verrat*	12	6	2	2.44	5.72	7.87	7.60	7.20	0.62	77.41	234.52	296.42	160.07
Zorn*	11	4	1	2.78	6.63	7.58	7.33	6.93	0.57	69.05	234.71	285.62	179.51
neutral words - male speaker													
Ablauf*	11	6	2	5.19	1.94	7.06	5.00	2.31	0.66	55.18	123.62	164.32	98.82
Abstand*	10	7	2	4.94	2.63	6.48	5.10	2.80	0.67	54.85	123.95	160.80	103.82
Anfahrt*	14	7	2	5.10	2.41	6.58	5.03	2.77	0.78	60.81	142.69	171.88	108.74
Anhang	13	6	2	4.94	2.28	6.90	4.97	2.63	0.48	60.02	135.84	167.04	97.64
Anlauf*	11	6	2	5.06	2.34	6.58	5.00	2.48	0.65	61.94	126.44	152.39	101.98
Ansatz*	11	6	2	5.06	1.84	6.97	4.97	2.40	0.74	63.86	138.07	159.65	110.72
Anzahl	10	6	2	5.10	2.06	6.68	5.03	2.87	0.67	61.36	139.61	169.27	106.60
Aufsatz*	13	7	2	4.94	2.59	5.42	5.03	2.72	0.80	60.44	132.56	157.83	104.02
Auskunft	10	8	2	5.19	2.41	6.52	5.00	2.23	0.89	57.24	131.06	157.08	95.89
Bescheid*	11	8	2	5.00	2.72	6.77	5.00	2.50	0.62	62.57	139.46	165.70	104.91
Bestand*	11	7	2	4.97	1.97	7.10	4.80	2.53	0.65	61.24	140.68	179.67	102.46
Dampf	13	5	1	4.94	2.63	3.90	5.03	2.17	0.42	64.15	137.31	169.01	102.74
Faktor*	11	6	2	4.97	2.34	6.55	5.20	2.73	0.65	49.37	141.33	174.54	108.43
Format	12	6	2	5.13	2.16	6.26	5.00	2.27	0.84	66.75	140.87	160.35	106.70
Formel*	11	6	2	4.97	2.66	6.97	4.97	3.00	0.58	65.83	144.49	166.20	110.64
Fracht*	13	6	1	4.91	2.59	3.65	5.07	2.53	0.64	65.40	139.97	161.65	113.33
Gebiet*	9	6	2	4.88	1.97	5.13	5.03	2.53	0.54	60.71	142.87	165.04	100.46
Gebrauch*	11	8	2	5.00	2.16	7.23	5.00	2.47	0.58	61.26	144.87	183.72	101.92

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Word	Frequency	Letters	Syllables	Visual Valence	Visual Arousal	Visual Concreteness	Auditory Valence	Auditory Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Golf*	10	4	1	5.16	2.47	3.52	5.10	2.43	0.47	64.96	141.91	171.56	105.67
Hälfte*	8	6	2	5.06	2.63	5.71	5.13	2.76	0.53	66.84	146.02	152.67	123.83
Import	12	6	2	5.06	2.44	6.06	5.03	2.27	0.64	57.44	138.70	163.13	116.30
Mitte*	8	5	2	4.97	2.47	6.10	5.10	2.80	0.41	55.63	128.79	150.22	99.29
Modul*	14	5	2	4.88	2.31	6.13	4.97	2.17	0.61	61.31	133.00	157.10	100.90
Phase*	10	5	2	5.06	2.06	6.97	5.07	2.86	0.59	62.62	160.24	180.26	122.95
Saal*	10	4	1	5.13	2.72	2.81	5.07	2.33	0.47	67.15	129.15	165.89	101.42
Satz*	9	4	1	5.13	1.78	5.58	4.93	2.33	0.61	64.57	145.39	164.92	113.95
Schema*	13	6	2	4.97	1.81	6.94	4.93	2.40	0.59	63.36	136.35	175.34	104.75
Sequenz	14	7	2	5.13	1.94	7.23	5.17	2.43	0.91	57.77	136.66	156.70	102.75
Silbe*	14	5	2	5.06	1.94	5.47	4.97	2.40	0.56	62.26	149.26	181.88	109.99
Sitz	10	4	1	5.06	2.31	2.74	5.03	2.17	0.60	63.24	141.58	156.74	123.85
Sorte*	12	5	2	5.06	2.03	7.03	4.90	2.30	0.59	57.28	139.16	162.72	106.91
Stahl*	11	5	1	4.91	2.41	2.61	5.00	2.80	0.59	63.54	145.19	193.01	116.49
Statut*	14	6	2	4.84	2.47	6.39	5.00	2.72	0.73	58.00	151.88	189.83	105.69
Stunde*	8	6	2	5.03	2.53	6.29	5.03	2.53	0.62	62.95	147.05	184.03	106.88
Summe*	9	5	2	5.03	2.69	6.71	4.97	2.31	0.48	62.52	140.05	157.42	108.37
Verb	15	4	1	5.09	1.78	6.55	5.00	2.55	0.51	66.60	142.35	161.73	110.39
Vorgang*	11	7	2	5.13	2.13	7.29	4.83	2.47	0.72	60.66	127.94	151.75	103.00
Zufuhr*	15	6	2	5.03	1.87	5.87	5.17	2.57	0.76	55.65	139.01	189.87	103.42
Zugang*	10	6	2	5.13	2.38	6.29	5.13	2.70	0.65	58.43	132.05	178.70	104.44
Zustand	9	7	2	5.06	2.56	7.39	5.07	2.55	0.83	56.77	136.78	182.21	100.87
positive words - male speaker													
Baby	11	4	2	7.34	5.88	2.45	2.73	6.63	0.58	64.36	212.22	305.26	121.24
Charme*	11	6	1	7.39	6.28	7.57	2.80	6.83	0.90	68.19	243.65	327.19	130.81
Engel*	10	5	2	7.63	6.13	4.61	2.70	6.33	0.62	65.28	212.27	327.78	121.62
Flirt*	14	5	1	7.41	6.88	6.68	2.60	7.13	1.13	70.38	265.47	334.08	161.43
Freiheit*	9	8	2	8.16	6.50	7.93	2.47	7.00	1.26	65.38	198.09	277.69	120.87
Freude*	9	6	2	7.53	7.16	7.52	3.00	7.03	0.87	66.41	228.10	332.35	129.97

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				Visual			Auditory						
Word	Frequency	Letters	Syllables	Valence	Arousal	Concreteness	Valence	Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Freund	9	6	1	7.63	7.31	4.29	2.67	7.23	0.92	66.69	244.62	355.33	127.04
Frieden*	9	7	2	8.00	6.41	8.39	2.80	6.73	0.95	64.77	227.50	312.75	125.97
Frühling*	11	8	2	7.81	6.16	6.13	2.50	7.13	1.03	64.11	238.76	344.25	131.16
Gefühl*	9	6	2	7.28	7.41	7.68	2.93	6.60	0.83	63.34	220.07	321.84	123.22
Genie*	12	5	2	7.88	7.31	7.32	2.97	6.03	0.81	68.74	194.35	247.25	120.93
Genuss*	12	6	2	7.13	7.00	7.35	2.77	6.13	0.71	70.94	265.19	346.26	201.92
Glück*	8	5	1	7.81	7.44	8.16	2.80	6.20	0.59	73.24	293.66	326.64	215.58
Himmel*	9	6	2	7.47	6.16	4.81	2.73	6.93	0.61	63.72	223.30	339.56	124.66
Humor	11	5	2	7.72	6.50	7.74	2.73	6.60	0.85	68.90	233.76	298.56	120.63
Kuss*	14	4	1	8.00	7.88	3.45	2.40	7.57	0.86	64.15	257.47	290.67	189.62
Lächeln	10	7	2	7.72	7.06	5.97	2.80	6.47	0.77	64.52	223.10	320.33	123.08
Lachen	11	6	2	7.78	6.52	5.94	2.60	6.73	1.06	65.39	262.07	341.36	156.41
Liebe*	8	5	2	8.03	7.69	8.16	2.53	6.97	0.78	65.27	238.08	332.95	143.93
Liebling	12	8	2	7.47	6.72	6.19	2.60	6.83	0.86	56.68	199.33	309.24	117.14
Liebster*	15	8	2	7.75	6.16	6.03	2.70	7.17	0.96	60.50	240.25	345.57	138.74
Lust*	9	4	1	7.03	7.28	7.87	2.77	6.43	0.74	70.72	247.03	316.50	173.48
Mama*	11	4	2	7.22	5.88	3.45	2.77	6.77	0.74	67.51	214.98	313.60	134.34
Musik	8	5	2	7.34	6.38	6.06	2.70	6.33	0.86	68.14	242.72	316.72	131.47
Party*	11	5	2	7.28	6.13	5.23	2.83	6.93	0.71	62.63	232.88	339.60	131.78
Perle*	13	5	2	7.13	5.87	2.55	2.90	6.62	0.57	67.42	252.68	349.73	138.13
Retter*	12	6	2	7.13	5.88	4.71	2.60	7.03	0.93	61.17	244.88	356.02	128.27
Sex*	10	3	1	7.56	8.19	5.06	2.73	6.90	0.80	72.76	291.26	336.11	194.06
Sieg*	8	4	1	7.56	6.28	7.06	2.77	6.87	0.62	70.49	239.79	349.13	157.39
Sieger*	10	6	2	7.47	6.31	5.13	2.50	7.30	1.00	68.94	222.67	382.38	134.14
Sommer*	9	6	2	7.97	6.22	5.73	2.37	6.67	0.74	66.76	221.49	307.68	141.71
Sonne*	9	5	2	7.53	6.28	2.77	2.80	6.93	0.68	67.27	215.75	306.76	129.59
Spass*	16	5	1	8.09	6.69	7.61	2.63	7.17	1.06	67.96	254.30	335.60	152.29
Traum	9	5	1	7.31	6.09	6.97	2.67	6.87	0.84	69.22	219.23	297.12	132.61
Trauung*	14	7	2	7.16	6.06	5.68	3.20	6.52	0.65	66.57	199.85	312.28	116.89
Treue	11	5	1	7.16	6.31	8.03	3.23	6.87	0.68	66.46	230.98	374.43	133.20
Triumph*	11	7	2	7.19	6.78	7.42	2.70	7.17	1.08	70.89	275.61	373.69	139.91
Vorspiel	13	8	2	7.22	6.78	6.35	2.93	6.47	1.06	57.03	194.02	335.19	114.38
Wahrheit*	9	8	2	7.91	6.13	8.19	2.47	6.97	1.02	62.08	207.32	316.41	123.10
Wunder*	10	6	2	7.59	7.13	8.16	2.53	7.60	1.10	63.90	253.13	401.10	133.33

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				Visual			Auditory						
Word	Frequency	Letters	Syllables	Valence	Arousal	Concreteness	Valence	Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
negative words - female speaker													
Aids*	11	4	1	2.03	7.22	6.52	7.67	7.87	0.53	78.63	417.40	512.53	235.99
Angst	8	5	1	2.16	6.97	7.81	7.73	7.57	0.50	72.83	339.09	429.18	260.06
Armut*	10	5	2	2.84	6.00	7.42	7.17	6.50	0.56	69.02	213.09	248.81	147.86
Bestie*	14	6	2	2.66	7.00	6.06	7.77	7.60	0.50	68.36	261.39	362.07	237.12
Biest*	15	5	1	2.94	6.88	5.29	7.57	6.90	0.50	72.30	350.94	407.71	255.63
Drogen*	10	6	2	2.22	7.06	3.19	7.57	7.10	0.50	77.24	305.26	392.23	102.86
Drohung	11	7	2	2.69	7.16	7.74	7.33	6.87	0.50	80.99	327.37	400.98	186.62
Elend	11	5	2	2.03	6.81	7.03	7.87	7.43	0.65	77.90	343.79	395.87	206.77
Feind*	10	5	1	2.28	7.13	6.27	7.90	7.37	0.54	77.74	362.72	422.17	218.47
Folter*	12	6	2	2.00	6.78	6.84	7.83	7.37	0.59	76.68	301.87	393.34	219.19
Furcht*	11	6	1	2.84	6.84	7.77	7.47	7.34	0.57	78.38	356.74	422.28	269.46
Geisel	13	6	2	2.13	7.03	4.43	7.67	7.30	0.55	77.78	325.66	430.61	173.45
Gewalt*	8	6	2	2.22	6.91	7.10	7.57	7.57	0.55	76.68	340.55	381.77	239.37
Grab	11	4	1	2.69	5.88	3.00	7.67	7.33	0.47	80.06	228.35	324.60	154.76
Hass*	12	4	1	2.28	7.66	7.81	7.67	6.90	0.39	80.17	315.82	330.92	299.95
Henker*	13	6	2	2.06	6.94	4.13	7.87	7.83	0.62	75.45	341.00	423.45	234.00
Hölle*	11	5	2	2.03	6.94	6.74	8.00	8.00	0.46	76.37	267.73	414.66	98.60
Krieg*	8	5	1	1.66	7.31	6.45	7.73	6.97	0.59	76.31	355.46	453.22	148.39
Krise	9	5	2	2.78	5.94	7.35	7.83	7.47	0.60	75.61	416.10	500.77	261.87
Leiche*	10	6	2	2.13	7.44	3.03	8.00	7.70	0.55	72.84	295.26	398.74	185.18
Lüge	11	4	2	2.94	7.06	7.50	7.63	7.10	0.56	78.04	398.52	520.17	218.00
Lügner*	13	6	2	2.78	7.06	6.74	7.80	7.33	0.56	64.80	262.45	398.86	153.50
Mord*	10	4	1	1.56	7.56	5.94	7.70	7.40	0.66	78.96	278.25	331.85	176.65
Mörder*	10	6	2	1.94	6.69	5.48	7.53	7.53	0.53	75.43	296.88	357.07	227.39
Opfer*	8	5	2	2.10	6.19	5.32	7.77	7.83	0.54	76.38	331.76	451.74	220.72
Räuber	11	6	2	2.94	5.72	3.77	7.53	7.13	0.55	73.58	211.33	304.80	127.34
Satan*	13	5	2	2.75	7.03	6.45	7.83	7.40	0.65	68.07	250.06	311.69	164.78
Schlampe*	16	8	2	2.75	7.06	5.29	7.87	7.90	0.74	69.96	331.58	387.85	232.70

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				Visual			Auditory						
Word	Frequency	Letters	Syllables	Valence	Arousal	Concreteness	Valence	Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Schmerz	11	7	1	2.94	6.56	7.45	7.90	8.13	0.83	65.66	180.58	203.91	137.80
Seuche	13	6	2	2.38	7.06	6.71	7.57	7.47	0.59	76.53	292.29	367.54	147.65
Streit*	8	6	1	2.25	5.63	6.87	7.87	7.60	0.71	78.08	346.43	391.37	221.65
Terror*	10	6	2	1.84	7.22	7.52	7.77	7.50	0.48	76.83	287.83	374.71	148.20
Teufel*	10	6	2	2.94	6.69	6.16	7.67	7.37	0.41	68.99	222.38	278.49	140.98
Tod*	8	3	1	1.91	7.22	6.94	7.53	7.40	0.37	79.28	361.31	456.48	261.74
Trauer*	11	6	2	2.59	6.84	7.81	7.86	7.40	0.57	75.07	253.76	323.91	144.61
Trauma*	13	6	2	2.78	6.94	7.13	7.70	7.50	0.59	72.58	225.29	270.32	141.76
Trennung*	10	8	2	2.88	7.25	6.65	7.93	7.33	0.52	74.85	268.40	321.91	164.41
Tumor*	13	5	2	2.19	6.78	3.65	7.87	7.33	0.69	79.75	297.81	388.35	157.09
Verrat*	12	6	2	2.44	5.72	7.87	7.80	7.52	0.66	82.44	317.76	375.41	226.07
Zorn*	11	4	1	2.78	6.63	7.58	7.67	7.70	0.50	76.22	344.96	441.69	178.99
neutral words - female speaker													
Ablauf*	11	6	2	5.19	1.94	7.06	5.03	2.17	0.58	51.57	165.69	195.50	144.48
Abstand*	10	7	2	4.94	2.63	6.48	4.80	2.86	0.55	53.79	188.30	252.95	144.22
Anfahrt*	14	7	2	5.10	2.41	6.58	4.76	2.55	0.73	58.09	177.69	211.46	139.24
Anhang	13	6	2	4.94	2.28	6.90	4.70	2.67	0.49	62.08	179.03	227.35	141.86
Anlauf*	11	6	2	5.06	2.34	6.58	4.87	2.38	0.67	64.88	178.75	212.28	148.49
Ansatz*	11	6	2	5.06	1.84	6.97	4.97	2.17	0.53	58.62	167.44	198.38	142.35
Anzahl	10	6	2	5.10	2.06	6.68	4.90	2.33	0.54	64.09	192.56	239.30	148.60
Aufsatz*	13	7	2	4.94	2.59	5.42	4.87	2.45	0.64	64.11	178.07	203.75	142.04
Auskunft	10	8	2	5.19	2.41	6.52	4.77	2.69	0.74	61.97	189.45	221.73	153.36
Bescheid*	11	8	2	5.00	2.72	6.77	5.10	2.20	0.61	60.57	175.18	206.03	143.43
Bestand*	11	7	2	4.97	1.97	7.10	4.93	2.03	0.59	54.50	174.63	214.55	155.40
Dampf	13	5	1	4.94	2.63	3.90	4.93	2.53	0.42	61.47	180.67	214.44	148.33
Faktor*	11	6	2	4.97	2.34	6.55	4.97	2.70	0.66	48.24	183.22	230.47	146.12
Format	12	6	2	5.13	2.16	6.26	4.93	2.50	0.83	67.01	186.33	221.59	73.28
Formel*	11	6	2	4.97	2.66	6.97	5.03	2.10	0.57	60.96	172.20	198.94	135.35
Fracht*	13	6	1	4.91	2.59	3.65	4.83	2.57	0.53	63.29	192.86	234.90	159.00

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Word	Frequency	Letters	Syllables	Visual Valence	Visual Arousal	Visual Concreteness	Auditory Valence	Auditory Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Gebiet*	9	6	2	4.88	1.97	5.13	4.93	2.53	0.51	58.98	179.45	215.28	146.83
Gebrauch*	11	8	2	5.00	2.16	7.23	4.97	2.27	0.56	59.30	172.97	203.32	146.83
Golf*	10	4	1	5.16	2.47	3.52	5.03	2.20	0.49	64.77	170.02	192.50	152.63
Hälfte*	8	6	2	5.06	2.63	5.71	4.87	2.87	0.49	59.68	215.62	246.83	146.88
Import	12	6	2	5.06	2.44	6.06	4.93	2.70	0.70	60.51	184.06	202.81	146.83
Mitte*	8	5	2	4.97	2.47	6.10	4.93	2.70	0.35	50.85	188.28	206.35	145.01
Modul*	14	5	2	4.88	2.31	6.13	4.93	2.23	0.59	65.27	180.12	200.10	143.87
Phase*	10	5	2	5.06	2.06	6.97	5.03	2.30	0.52	65.79	177.77	196.45	139.33
Saal*	10	4	1	5.13	2.72	2.81	5.00	2.00	0.51	62.74	171.44	205.26	147.54
Satz*	9	4	1	5.13	1.78	5.58	4.93	2.10	0.63	59.74	174.87	190.48	156.10
Schema*	13	6	2	4.97	1.81	6.94	5.07	2.23	0.58	63.69	179.36	207.21	149.29
Sequenz	14	7	2	5.13	1.94	7.23	4.97	2.33	0.68	60.16	187.76	234.42	152.52
Silbe*	14	5	2	5.06	1.94	5.47	4.93	1.87	0.43	64.25	177.16	195.92	84.70
Sitz	10	4	1	5.06	2.31	2.74	4.90	2.23	0.47	64.83	191.32	215.62	169.73
Sorte*	12	5	2	5.06	2.03	7.03	5.07	2.37	0.53	54.68	173.81	200.37	148.74
Stahl*	11	5	1	4.91	2.41	2.61	5.03	2.47	0.49	63.95	189.74	227.99	162.59
Statut*	14	6	2	4.84	2.47	6.39	4.93	2.30	0.69	53.10	192.50	245.89	146.75
Stunde*	8	6	2	5.03	2.53	6.29	5.10	2.07	0.66	59.39	173.10	206.94	146.38
Summe*	9	5	2	5.03	2.69	6.71	5.00	2.30	0.44	64.97	168.86	206.47	85.63
Verb	15	4	1	5.09	1.78	6.55	4.93	1.97	0.42	60.70	174.08	208.51	145.84
Vorgang*	11	7	2	5.13	2.13	7.29	4.90	2.33	0.53	61.68	168.84	210.97	76.10
Zufuhr*	15	6	2	5.03	1.87	5.87	5.07	2.07	0.55	56.09	176.08	223.80	141.08
Zugang*	10	6	2	5.13	2.38	6.29	5.00	2.57	0.50	64.31	192.03	254.54	153.46
Zustand	9	7	2	5.06	2.56	7.39	4.97	2.33	0.85	59.12	183.24	255.48	144.79
positive words - female speaker													
Baby	11	4	2	7.34	5.88	2.45	2.53	7.24	0.91	67.87	331.31	509.61	152.79
Charme*	11	6	1	7.39	6.28	7.57	2.43	6.97	0.90	56.18	177.46	206.39	145.29
Engel*	10	5	2	7.63	6.13	4.61	2.69	6.87	0.49	69.05	280.32	389.66	167.35
Flirt*	14	5	1	7.41	6.88	6.68	2.90	6.52	0.78	74.90	312.37	396.01	179.90

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				Visual			Auditory						
Word	Frequency	Letters	Syllables	Valence	Arousal	Concreteness	Valence	Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Freiheit*	9	8	2	8.16	6.50	7.93	2.87	6.70	0.76	65.91	262.69	381.13	146.79
Freude*	9	6	2	7.53	7.16	7.52	2.47	7.43	0.77	71.58	313.10	497.56	103.97
Freund	9	6	1	7.63	7.31	4.29	2.50	6.77	0.74	74.04	332.61	445.10	155.38
Frieden*	9	7	2	8.00	6.41	8.39	2.93	5.63	0.66	71.65	279.16	374.72	161.32
Frühling*	11	8	2	7.81	6.16	6.13	2.90	6.70	0.64	74.13	262.63	376.75	119.82
Gefühl*	9	6	2	7.28	7.41	7.68	2.67	7.03	0.79	70.23	302.34	398.76	170.13
Genie*	12	5	2	7.88	7.31	7.32	2.63	6.87	0.71	75.65	337.54	446.89	174.81
Genuss*	12	6	2	7.13	7.00	7.35	2.23	7.62	1.33	66.43	209.32	246.53	169.24
Glück*	8	5	1	7.81	7.44	8.16	3.00	6.50	0.41	72.16	319.93	374.61	234.82
Himmel*	9	6	2	7.47	6.16	4.81	2.60	7.50	0.86	74.45	308.57	450.59	174.26
Humor	11	5	2	7.72	6.50	7.74	2.87	6.27	0.58	74.03	367.25	594.05	133.88
Kuss*	14	4	1	8.00	7.88	3.45	3.23	5.79	0.41	54.65	240.30	267.94	202.51
Lächeln	10	7	2	7.72	7.06	5.97	2.67	6.60	0.49	73.26	350.21	470.71	178.04
Lachen	11	6	2	7.78	6.52	5.94	3.03	5.83	0.55	65.53	261.34	360.83	165.32
Liebe*	8	5	2	8.03	7.69	8.16	2.37	7.04	0.81	67.45	258.86	316.42	173.66
Liebling	12	8	2	7.47	6.72	6.19	2.50	6.77	0.75	71.37	326.77	414.38	173.60
Liebster*	15	8	2	7.75	6.16	6.03	2.70	6.50	0.70	58.38	213.03	261.11	163.66
Lust*	9	4	1	7.03	7.28	7.87	2.80	6.73	0.66	74.32	377.40	546.12	223.71
Mama*	11	4	2	7.22	5.88	3.45	2.17	7.37	1.01	69.06	331.52	498.36	167.73
Musik	8	5	2	7.34	6.38	6.06	2.70	6.55	0.54	69.96	286.54	328.42	247.38
Party*	11	5	2	7.28	6.13	5.23	2.60	7.00	0.70	60.42	365.66	554.76	95.36
Perle*	13	5	2	7.13	5.87	2.55	2.37	6.93	0.80	65.06	214.66	253.15	168.80
Retter*	12	6	2	7.13	5.88	4.71	2.63	7.20	0.71	63.82	204.59	372.93	71.13
Sex*	10	3	1	7.56	8.19	5.06	2.47	7.20	0.84	75.14	396.52	493.26	282.70
Sieg*	8	4	1	7.56	6.28	7.06	2.83	5.97	0.68	76.10	311.81	420.34	176.36
Sieger*	10	6	2	7.47	6.31	5.13	2.50	7.73	0.89	74.08	379.60	629.84	167.93
Sommer*	9	6	2	7.97	6.22	5.73	2.87	6.47	0.60	74.55	223.59	278.86	169.30
Sonne*	9	5	2	7.53	6.28	2.77	2.53	7.00	0.80	72.28	248.52	338.20	178.50
Spass*	16	5	1	8.09	6.69	7.61	2.40	7.43	1.04	80.78	328.55	620.26	181.43
Traum	9	5	1	7.31	6.09	6.97	2.43	6.93	0.73	60.27	191.29	215.13	168.40
Trauung*	14	7	2	7.16	6.06	5.68	2.80	7.37	0.90	73.69	327.44	495.96	134.57
Treue	11	5	1	7.16	6.31	8.03	2.70	6.47	0.69	68.83	229.00	312.88	116.28
Triumph*	11	7	2	7.19	6.78	7.42	2.87	6.80	0.77	71.11	341.31	447.23	174.83
Vorspiel	13	8	2	7.22	6.78	6.35	2.27	7.43	1.45	59.28	210.21	278.71	164.79

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				Visual			Auditory						
Word	Frequency	Letters	Syllables	Valence	Arousal	Concreteness	Valence	Arousal	Duration	Mean Intensity	Mean Pitch	Max Pitch	Min Pitch
Wahrheit*	9	8	2	7.91	6.13	8.19	2.83	6.67	0.85	69.48	261.45	377.14	155.45
Wunder*	10	6	2	7.59	7.13	8.16	2.50	6.83	0.88	69.79	308.70	428.23	192.40

Table C.1: List of all stimuli used in the experiments. Asterisk marked words were part of the 90 words selection, see Section 7.2.

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List of Abbreviations

$^\circ$	Degree
μ**V**	microVolt
ω^2	Omega squared
AC	Anterior Commissure
ACC	Anterior Cingulate Cortex
ADHD	Attention Deficit Hyperactivity Disorder
Ag-AgCl	silver-silverchlorid
ANOVA	Analysis Of Variance
ANT	Attention Network Test
ATQ	Adult Temperament Questionnaire
BA	Brodmann Area
BOLD	Blood-Oxygen-Level Dependent
cm	centimeter
DASS	Depression Anxiety Stress Scales
DLPFC	Dorsolateral Prefrontal Cortex
EEG	Electroencephalogram
EPI	Echo Planar Imaging
fMRI	functional Magnetic Resonance Imaging

FOV	Field Of View
FWHM	Full Width At Half Maximum
g	gram
H	Hydrogen
Hz	Hertz
IFG	Inferior Frontal Gyrus
kΩ	kiloOhm
kHz	kiloHertz
log	Logarithm
LRP	Lateralized Readiness Potential
MDEFT	Modified Driven Equilibrium Fourier Transform
MEG	Magnetoencephalography
ml	milliliter
mm	millimeter
ms	millisecond
NMR	Nuclear Magnetic Resonance
OFC	Orbitofrontal Cortex
PC	Posterior Commissure
PET	Positron Emission Tomography
ROI	Region Of Interest
RT	Reaction Time

s second

SD Standard Deviation

SSVEP Steady-State Visual Evoked Potentials

STG Superior Temporal Gyrus

VEN von Economo Neurons

VMPFC Ventromedial Prefrontal Cortex

voxel Portmanteau of the words volumetric and pixel (**pic**ture **el**ement).

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Selbständigkeitserklärung

Hiermit erkläre ich, dass die vorliegende Arbeit ohne unzulässige Hilfe und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt wurde und dass die aus fremden Quellen direkt oder indirekt übernommenen Gedanken in der Arbeit als solche kenntlich gemacht worden sind.

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Leipzig, den 26. Juni 2008

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EXPLORING EXECUTIVE ATTENTION IN EMOTION: ERP AND FMRI EVIDENCE

Universität Leipzig, Dissertation

229 pages, 499 references, 29 figures, 32 tables

Paper The goal of the present dissertation was to investigate the influence of emotional stimuli on executive control of attention. Emotional stimuli signal relevance and importance of a situation, which requires fast detection of stimuli and rapid responses. Previous research could show that emotional stimuli orient spatial attention and increase phasic alertness. However, there is little evidence investigating an emotional influence on executive attention. It describes the ability to detect conflict between competing activations, e.g., response tendencies, and resolves conflict through selection and commitment of resources. To investigate the time-course and the neural basis of an interaction of emotion and executive attention, event-related potentials (ERP) of the electroencephalogram (EEG) and functional magnetic resonance imaging (fMRI) were applied.

A first set of experiments aimed at the effect of visually presented emotional words on performance in a flanker task in which participants reacted to a target stimulus, but ignored incongruent flanker stimuli. Experiment 1 showed that processing of conflicting stimuli was facilitated when these were negative emotional, e.g., murderer, war, or hatred. Also, the conflict sensitive N200 ERP component showed a corresponding amplitude modulation suggesting a rapid integration of conflict and emotion information. Similar results were obtained in Experiment 2 for positive emotional words such as winner, kiss, or joy. Experiment 3 investigated the neural basis and yielded conflict activation in the dorsal anterior cingulate cortex (ACC), and emotion related activity in the amygdala. The ventral ACC showed an interaction of emotion and conflict.

The second set of experiments showed that these effects generalize to a different form of conflict (stimulus-response incongruency) and to a different sensory modality (auditory).

Additionally, interindividual differences in subclinical depression, anxiety, and temperamental effortful control were measured and showed associations with the effects.

In conclusion, executive control of attention is enhanced in reaction to emotional stimuli in the environment. This seems to be a very fast process and involves activation of the ventral part of the ACC.

Referat Das Ziel der vorliegenden Dissertation war die Untersuchung des Einflusses emotionaler Reize auf die exekutive Kontrolle von Aufmerksamkeit. Emotionale Reize signalisieren die Bedeutsamkeit einer Situation, es ist daher notwendig diese schnell zu entdecken und rasch auf sie zu reagieren. Interessanterweise, konnte gezeigt werden, dass emotionale Reize räumliche Aufmerksamkeit lenken und auch kurzfristig Wachheit erhöhen können. Es gibt allerdings kaum Befunde dazu ob die exekutive Kontrolle von Aufmerksamkeit in Reaktion auf emotionale Stimuli verändert ist. Exekutive Aufmerksamkeit bezeichnet das Entdecken konflikthafter Aktivierungen, z.B. entgegengesetzter Verhaltenstendenzen, und das Lösen dieses Konflikts durch Selektion und Zuweisung von Ressourcen. Um den zeitlichen Verlauf einer Interaktion exekutiver Aufmerksamkeit mit Emotion, sowie die neuronalen Grundlagen derselben zu untersuchen wurden ereigniskorrelierte Potentiale (EKP) des Elektroenzephalogramms (EEG) und funktionelle Magnetresonanztomographie (fMRT) angewendet.

Eine erste Gruppe von Experimenten untersuchte den Effekt visuell präsentierter emotionaler Worte auf die Leistung in einer flanker-Aufgabe in der die Probanden auf einen Zielreiz reagieren, inkongruente flanker-Reize aber ignorieren sollten. Experiment 1 zeigte, dass die Verarbeitung konflikthafter Stimuli beschleunigt war, wenn diese negativ emotional waren, z.B. Mörder, Krieg oder Hass. Außerdem zeigte die Konflikt-sensitive N200 EKP-Komponente eine Amplitudenmodulation was auf eine sehr rasche Integration der Konflikt- und Emotionsinformation schließen lässt. Ähnliche Ergebnisse fanden sich in Experiment 2 für emotional positive Worte, z.B. Sieger, Kuss oder Freude. Experiment 3 untersuchte die neuronalen Korrelate und erbrachte Konflikt-Aktivierung im dorsalen anterioren cingulären Cortex (ACC), Emotions-Aktivierung in der Amygdala und eine Interaktion im ventralen Teil des ACC.

Die zweite Gruppe von Experimenten konnte zeigen, dass diese Effekte sich auf andere Formen von Konflikt (Stimulus-Reaktions Inkongruenz) und auf andere sensorische Modalitäten (auditiv) generalisieren lassen. Zusätzlich wurden interindividuelle Unterschiede in

subklinischer Depressivität, Ängstlichkeit und der Temperamentseigenschaft effortful control gemessen, die im Zusammenhang zu den oben beschriebenen Effekten stehen.

Es lässt sich schlussfolgern, dass die exekutive Kontrolle von Aufmerksamkeit in Reaktion auf emotionale Reize in der Umwelt moduliert ist. Dies geschieht sehr rasch nach der ersten Präsentation der Stimuli und scheint auf Aktivierung im ventralen Teil des ACC zu beruhen.